Southwest Regional Partnership on Carbon Sequestration

Project Overview

DE-PS26-O3NT41983

November 17, 2004

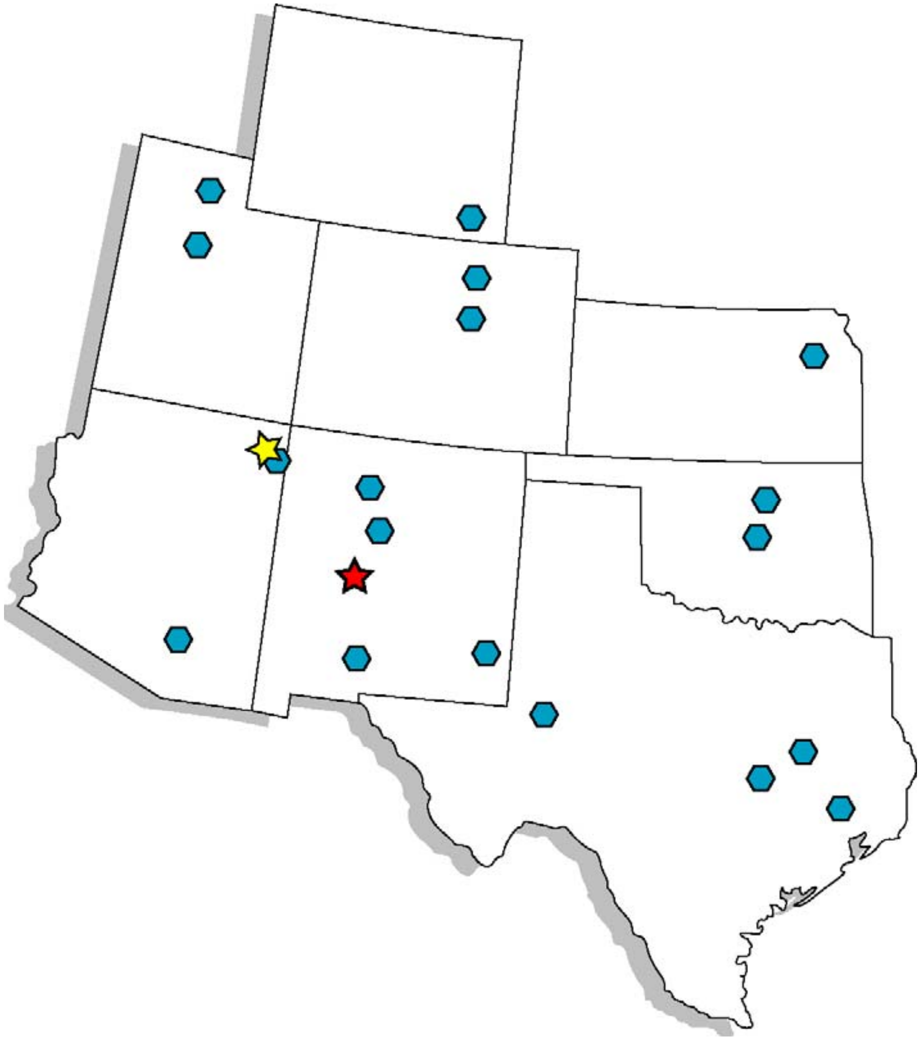
NETL Regional Partnerships Annual Review Meeting, Pittsburgh

Brian McPherson
New Mexico Institute of Mining and Technology

Outline

- Overview of Region and Partners
- Overview of Partnership Organization and Management
- Summary of Tasks and Working Group Efforts
- Southwest "Test Case" - Prototype for Final Analyses
- Summary of Phase II Pilot Options

Partners



In all partner states:

- major universities
- geologic survey
- other state agencies

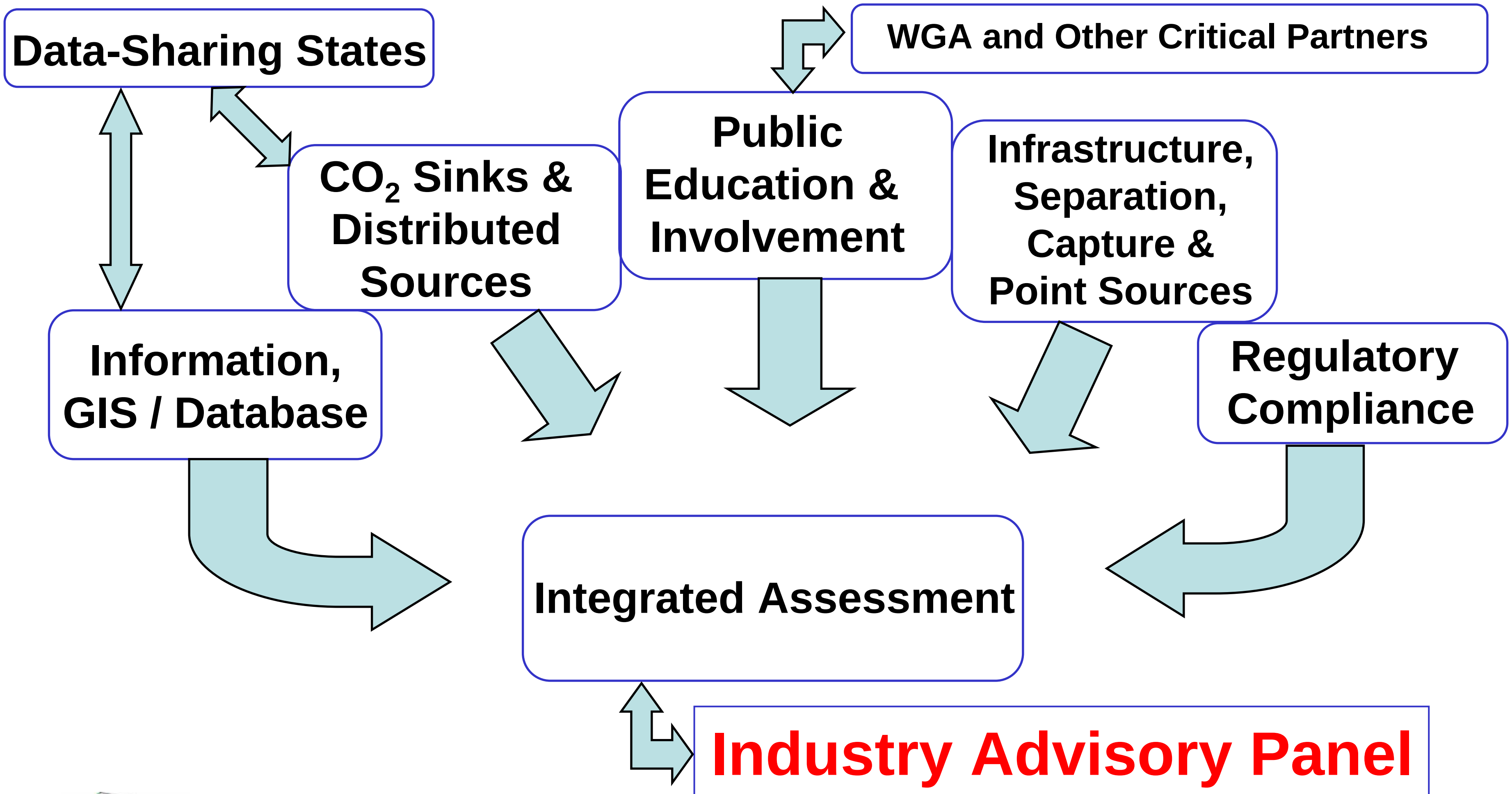
as well as

- Western Governors Association
- five major utilities
- seven energy companies
- three federal agencies
- the Navajo Nation
- many other critical partners

Outline

- Overview of Region and Partners
- Overview of Partnership Organization and Management
- Summary of Tasks and Working Group Efforts
- Southwest "Test Case" - Prototype for Final Analyses
- Summary of Phase II Pilot Options

Working Groups



Outline

- Overview of Region and Partners
- Overview of Partnership Organization and Management
- Summary of Tasks and Working Group Efforts
- Southwest "Test Case" - Prototype for Final Analyses
- Summary of Phase II Pilot Options

Summary of Working Groups' Progress

- Point Sources Group
- Separation/Capture/Transportation Group
- Sinks/Capacities Group
- Regulatory Group
- MMV and Risk Assessment Group
- Outreach and Public Involvement Group
- Database / Information Group
- Integrated Assessment Group

Point Sources Group

- **Examine and catalogue all point sources of CO_2 in the region, including**
  - Coal-fired plants
  - Gas-fired plants
  - Cement plants
  - Other processing plants
  - Etc.

For Each State in Region

- **CO_2 Emissions by Source**
  - Energy usage
  - Industry (non-energy)
  - Data for 2000
- **Electrical Generation Fuel Type**
  - Tons of CO_2 generated per year
  - Number of plants
  - Data for 2000
- **Number of Plants**
  - Major CO_2 producing industries

General Map of Sources and Pipelines

- *electrical power plants*
- *cement & other processing plants*
- *urban centers*
- *non-point sources (agriculture, automobiles, etc.)*

Total regional point source emissions ~10^8 t/yr.

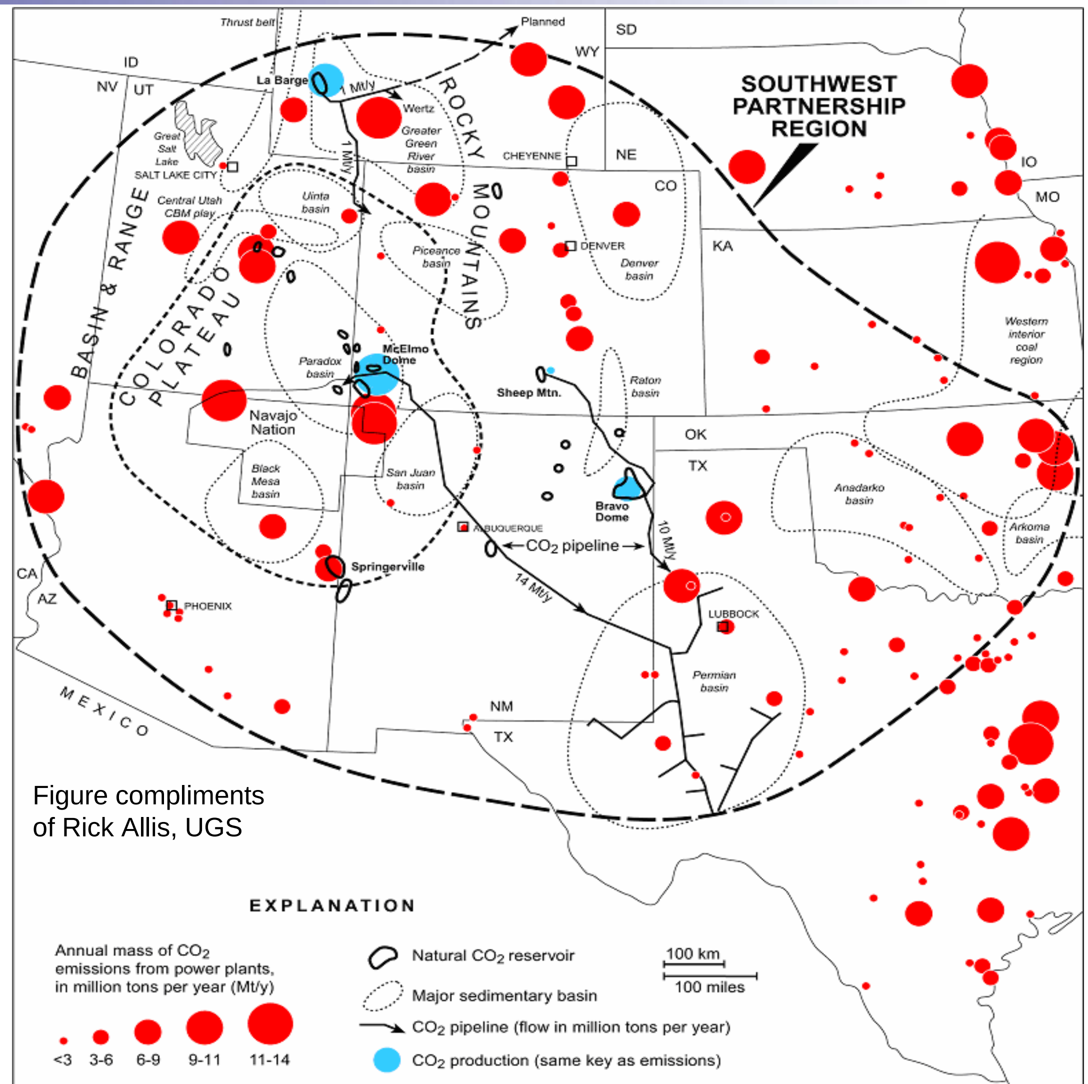
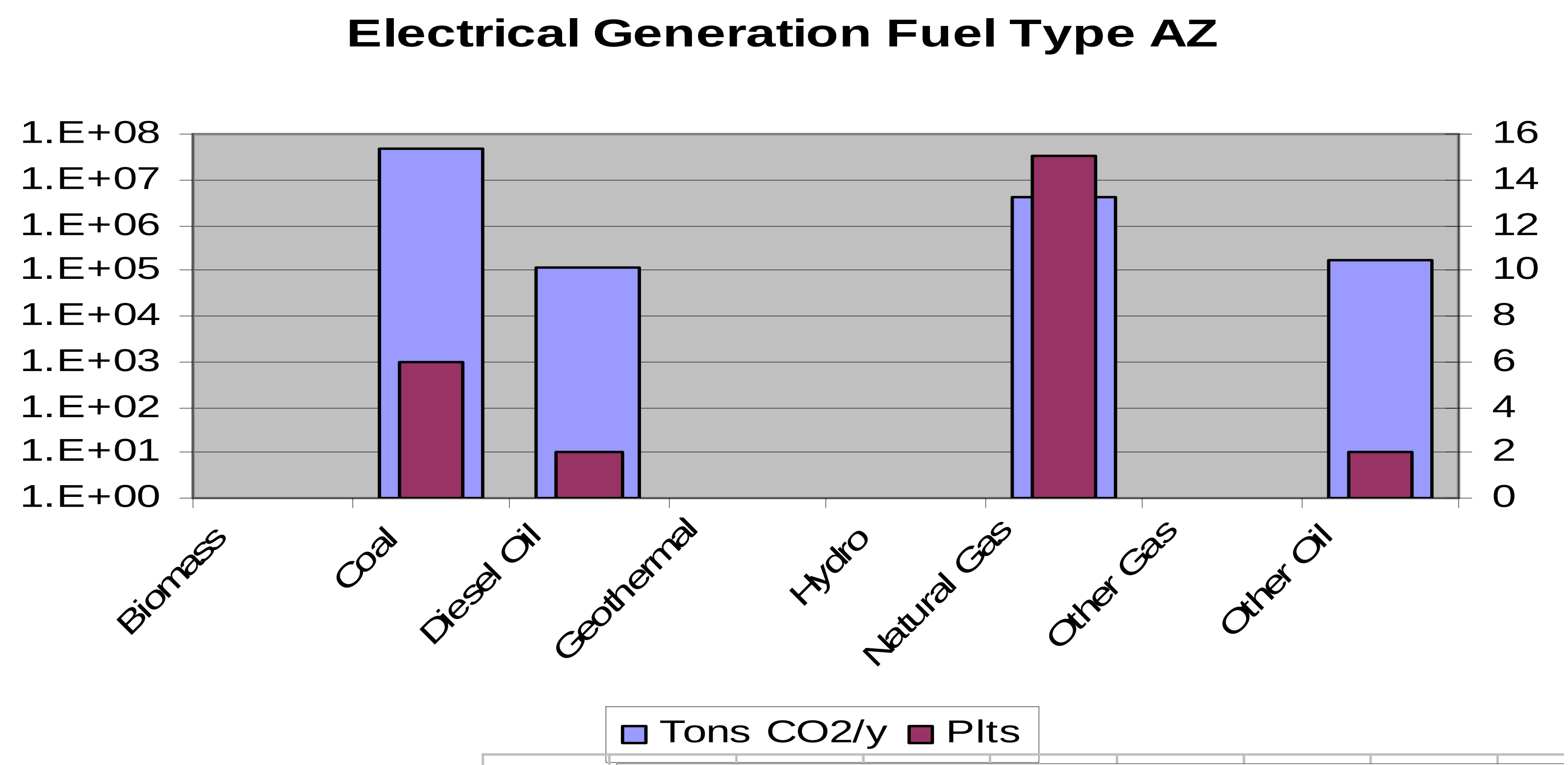
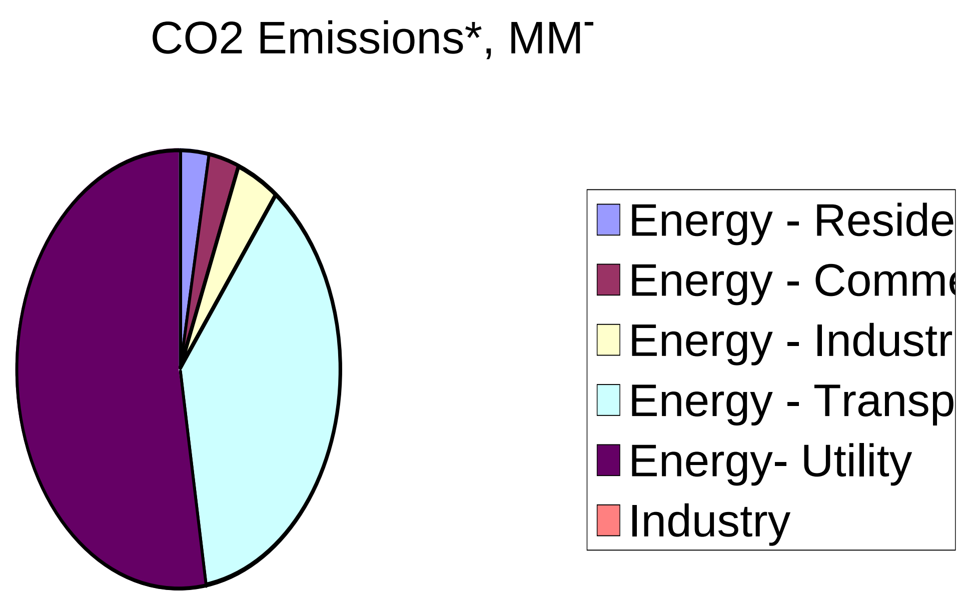


Figure compliments of Rick Allis, UGS

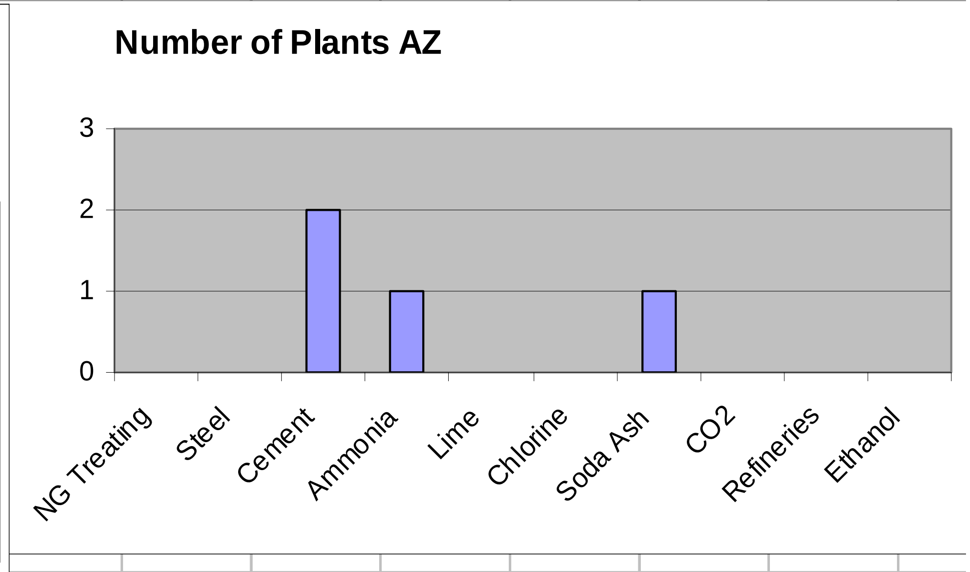
ARIZONA



Electrical Generation Fuel Type AZ
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
16
14
12
10
8
6
4
2
0
Biomass
Coal
Diesel Oil
Geothermal
Hydro
Natural Gas
Other Gas
Other Oil
Tons CO2/y
Plts

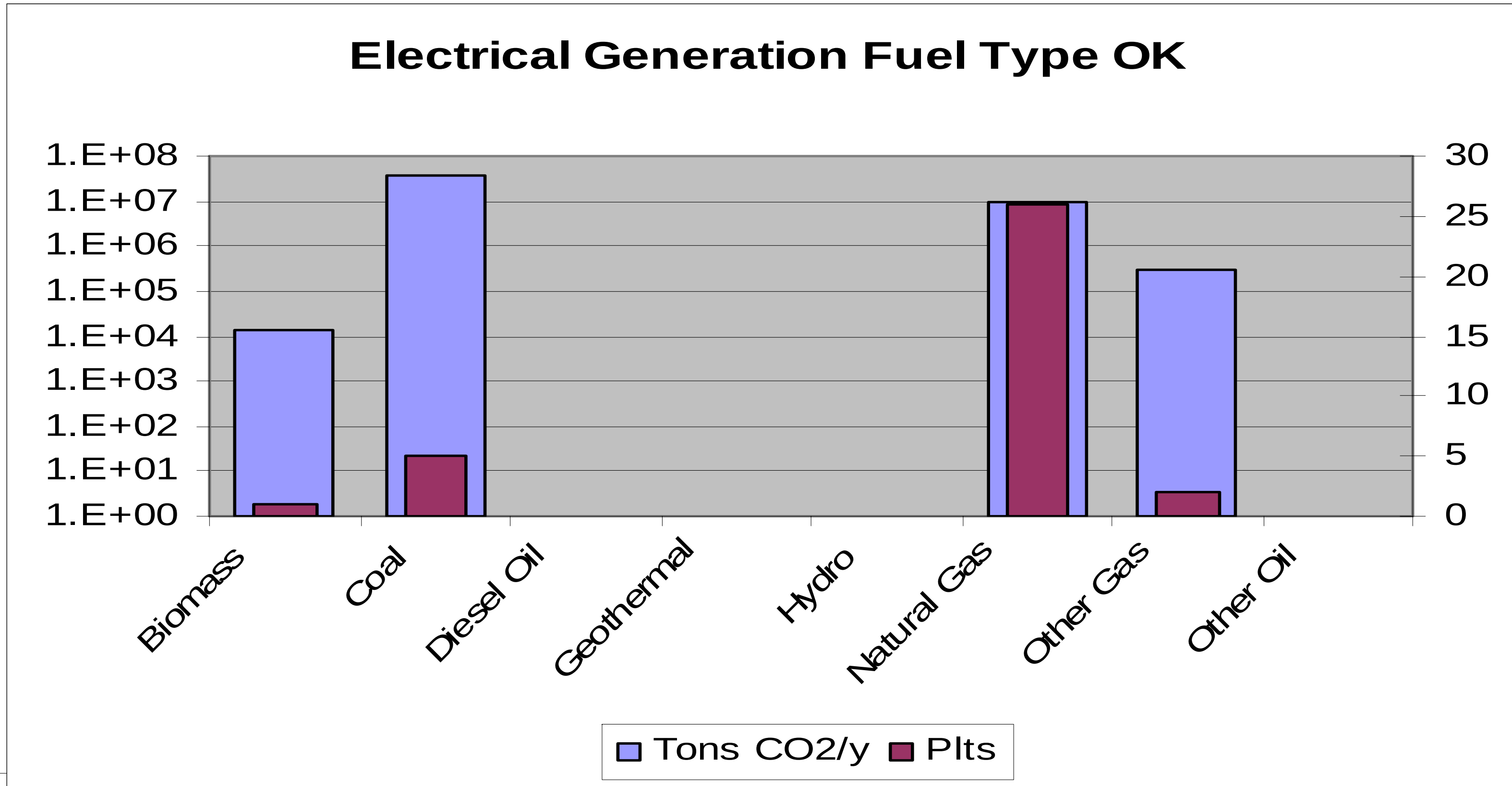


CO2 Emissions*, MM
Energy - Reside
Energy - Comme
Energy - Industr
Energy - Transp
Energy- Utility
Industry

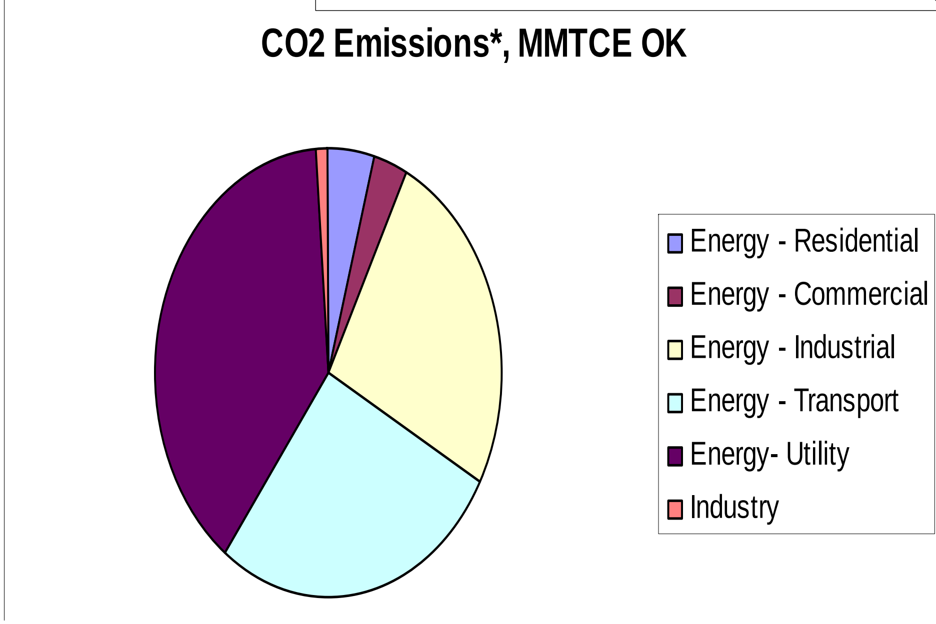


Number of Plants AZ
3
2
1
0
NG Treating
Steel
Cement
Ammonia
Lime
Chlorine
Soda Ash
CO2
Refineries
Ethanol

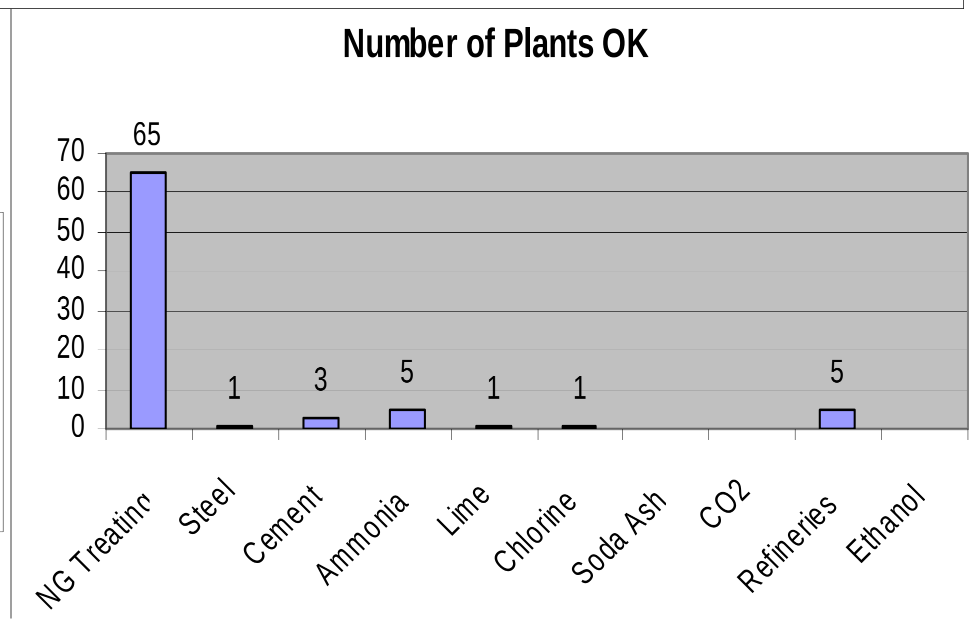
OKLAHOMA



Electrical Generation Fuel Type OK
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
30
25
20
15
10
5
0
Biomass
Coal
Diesel Oil
Geothermal
Hydro
Natural Gas
Other Gas
Other Oil
Tons CO2/y
Plts

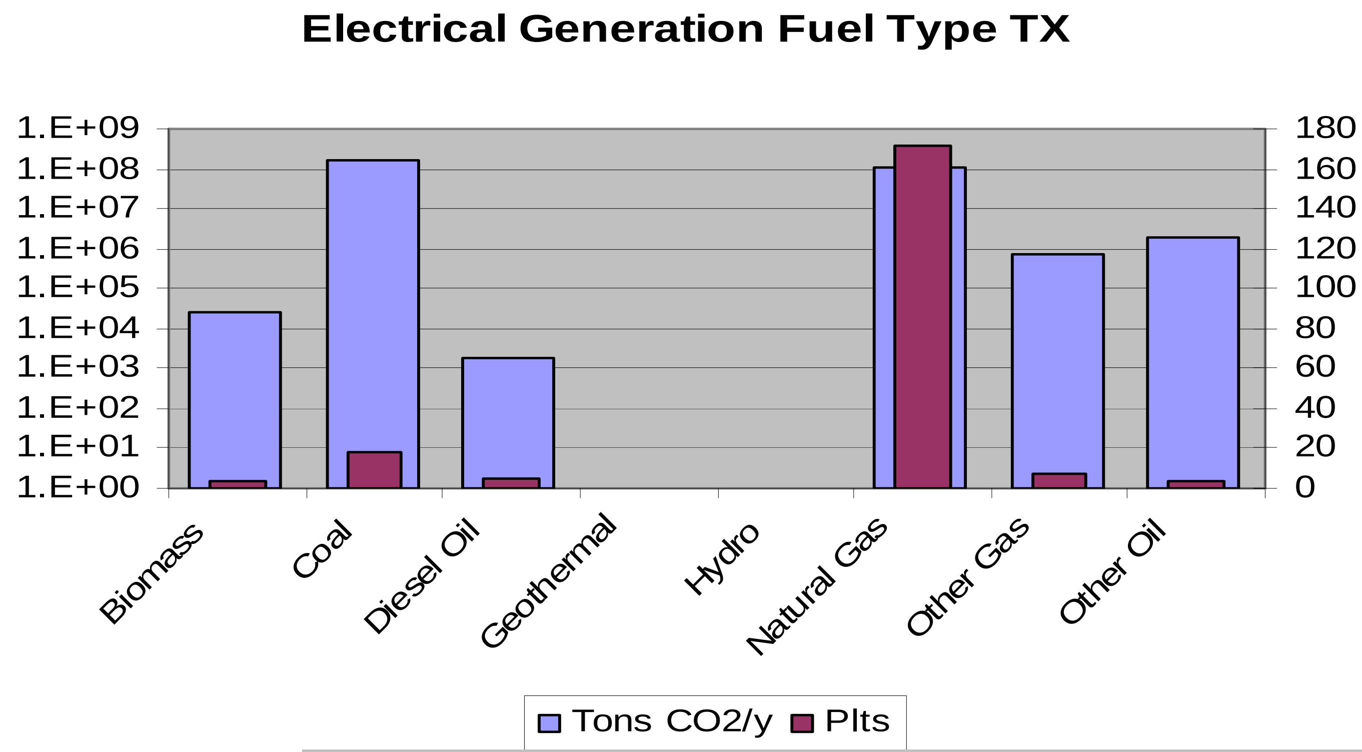


CO2 Emissions*, MMTCE OK
Energy - Residential
Energy - Commercial
Energy - Industrial
Energy - Transport
Energy- Utility
Industry

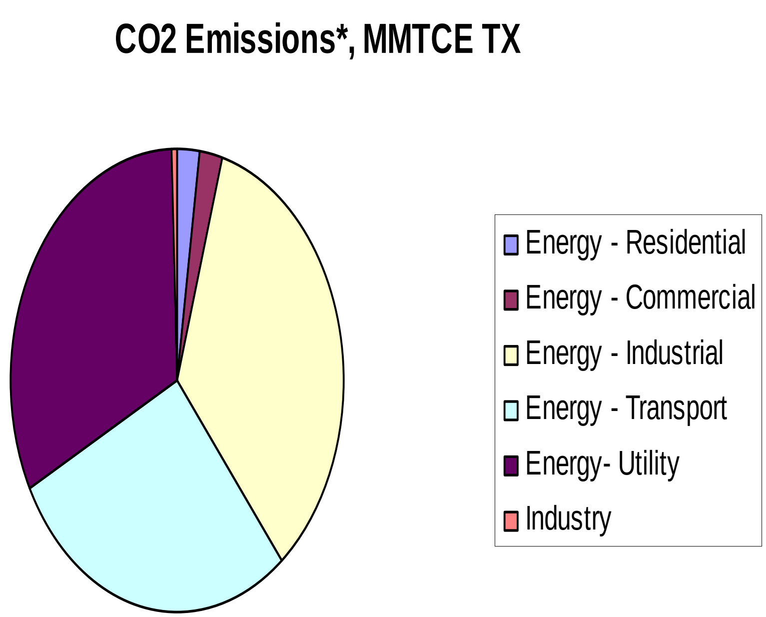


Number of Plants OK
70
60
50
40
30
20
10
0
65
1
3
5
1
1
5
NG Treatinc
Steel
Cement
Ammonia
Lime
Chlorine
Soda Ash
CO2
Refineries
Ethanol

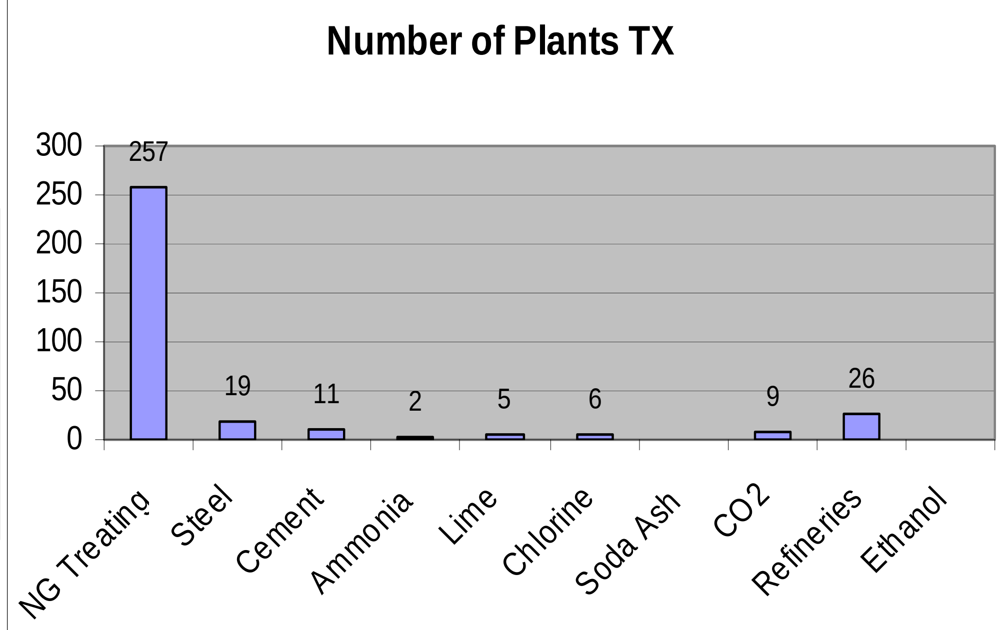
TEXAS



Electrical Generation Fuel Type TX
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
180
160
140
120
100
80
60
40
20
0
Biomass
Coal
Diesel Oil
Geothermal
Hydro
Natural Gas
Other Gas
Other Oil
Tons CO2/y
Plts

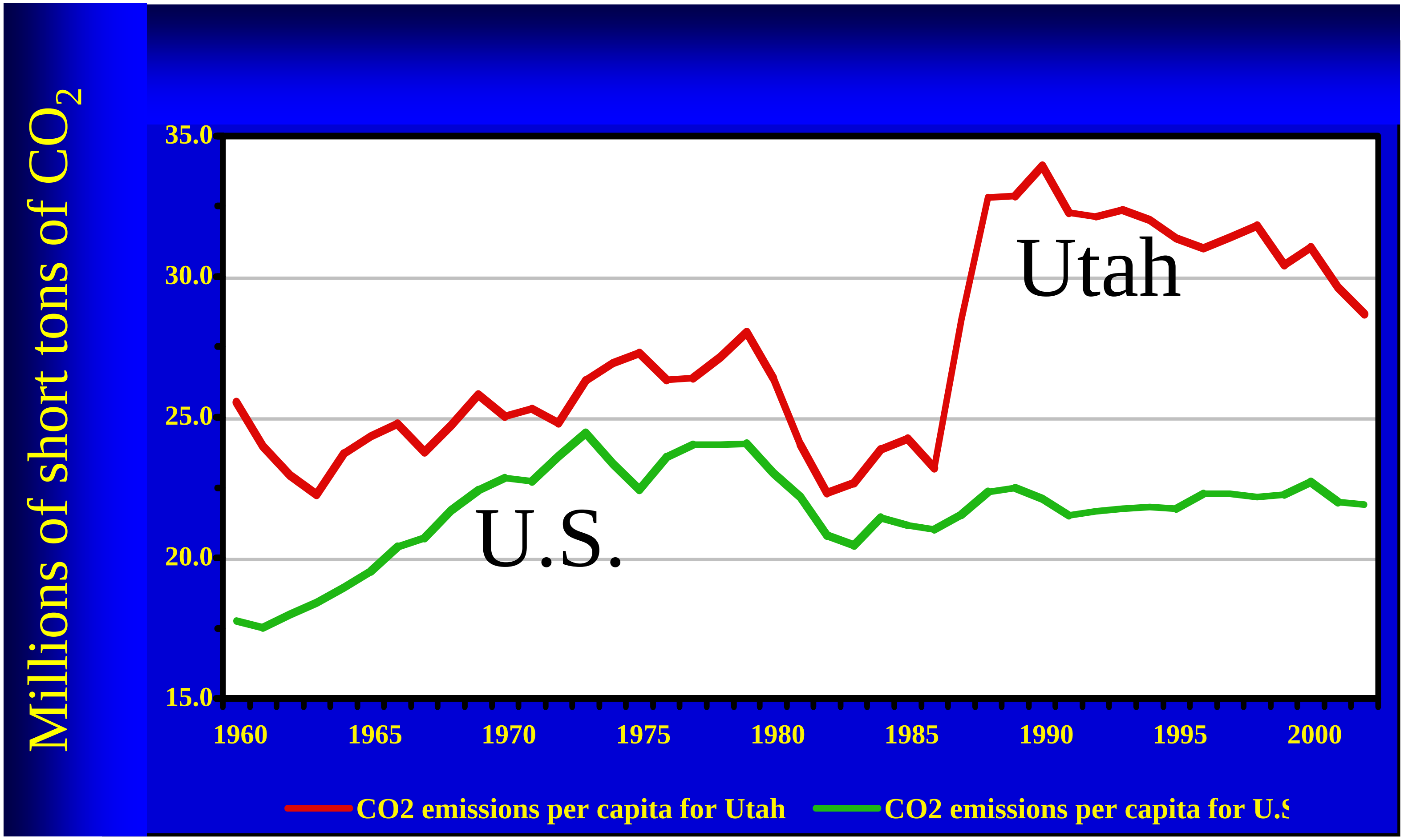


CO2 Emissions*, MMTCE TX
Energy - Residential
Energy - Commercial
Energy - Industrial
Energy - Transport
Energy- Utility
Industry



Number of Plants TX
300
250
200
150
100
50
0
257
19
11
2
5
6
9
26
NG Treating
Steel
Cement
Ammonia
Lime
Chlorine
Soda Ash
CO2
Refineries
Ethanol

Emissions per capita (fossil fuels)



Southwest Regional Partnership
on Carbon Sequestration

Summary of Working Groups' Progress

- Point Sources Group
- Separation/Capture/Transportation Group
- Sinks/Capacities Group
- Regulatory Group
- MMV and Risk Assessment Group
- Outreach and Public Involvement Group
- Database / Information Group
- Integrated Assessment Group

CO_2 Capture

- **Reviewed capture literature and capture technologies in use in each state:**
  - MEA (monoethanolamine) is "commercial technology"
    - Notwithstanding limited data in large coal-fired power plants
    - Costs of $40 – 60 per ton CO_2 captured incl. transport + liquefaction (but not sequestration)
    - IGCC is more expensive currently but results in lower avoided costs when CO_2 capture is required – physical solvents, not MEA are used

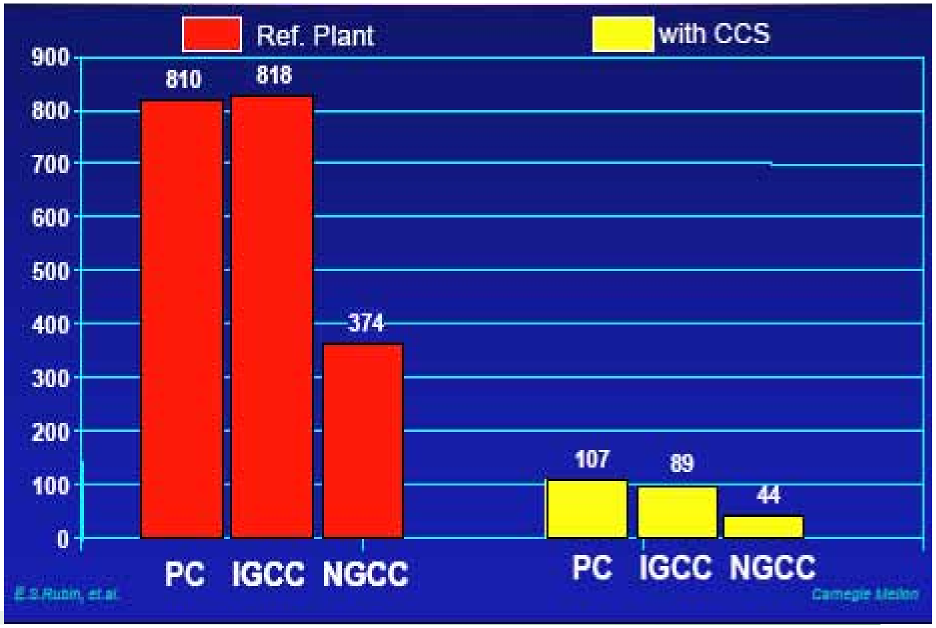
CO_2 Capture - Caveats

- **Not totally proven commercial technology for large-scale power plants**
- **Least-cost options depend on a myriad of factors:**
  - Plant capacity factor, type of coal, plant type (IGCC etc.), pollution controls? - scrubbers etc., EOR an option?, distance to sinks, terrain, age of plant, coal costs, regional electricity prices, labor costs
- **SW Regional Partnership will use the IECM-CS mod framework for capture costs:**
  - transparent assumptions, realistic level of detail, flexible inputs, “apple-to-apple” basis

Integrated Environmental Control Model, is publicly available from the CMU Center for Energy and Environmental Studies website http://www.iecm-online.com/cees_download.htm

CO_2 Capture – new technology

- **New solvents to replace MEA, KS-1 for example, are being commercialized**
- **Optimized and integrated MEA designs – *CO_2 Capture Project – substantial cost reductions***
- **Oxycombustion – very small-scale testing underway**
- **IGCC – nearing acceptance despite higher costs (w/o CO_2 capture); AEP announced it will build an IGCC power plant**
  - ½ the avoided cost of CO_2 capture
- **Numerous other developments underway – 10+ year development timeframes**



CO_2 Capture - Conclusions

- **Capture is expensive – C.O.E. may increase 100% for conventional technology (PC plants, MEA)**
- **Emerging technology can reduce the adoption costs for CO_2 capture, but COE still goes up 50%**
- **Incentives, tax credits, emissions trading, technology breakthroughs, additional demonstrations of emerging technology, mandates required before CO2 capture becomes widely employed**

Summary of Working Groups' Progress

- Point Sources Group
- Separation/Capture/Transportation Group
- Sinks/Capacities Group
- Regulatory Group
- MMV and Risk Assessment Group
- Outreach and Public Involvement Group
- Database / Information Group
- Integrated Assessment Group

Objectives

- **Identify – sink options in the region**
  - terrestrial
  - geologic
  - engineered-mineralization
  - Distribution, nature and size of potential sites
  - Type of data necessary for characterization
  - Sources of data
- **Assemble data in appropriate GIS format**
- **Evaluate and rank options**

Terrestrial

Terrestrial Capacities

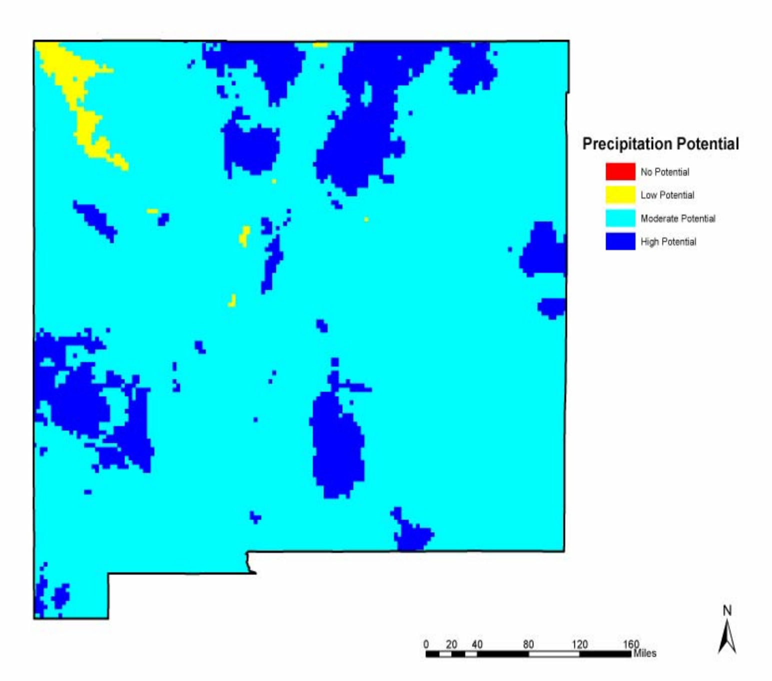
- test case “subregional analysis” completed; regional analysis underway
- major assumptions:

  a) land use is unlikely to change solely in response to sequestration incentives

  b) existing government conservation programs offer the most cost-effective means of increasing carbon storage and reducing risk of loss at the regional scale.

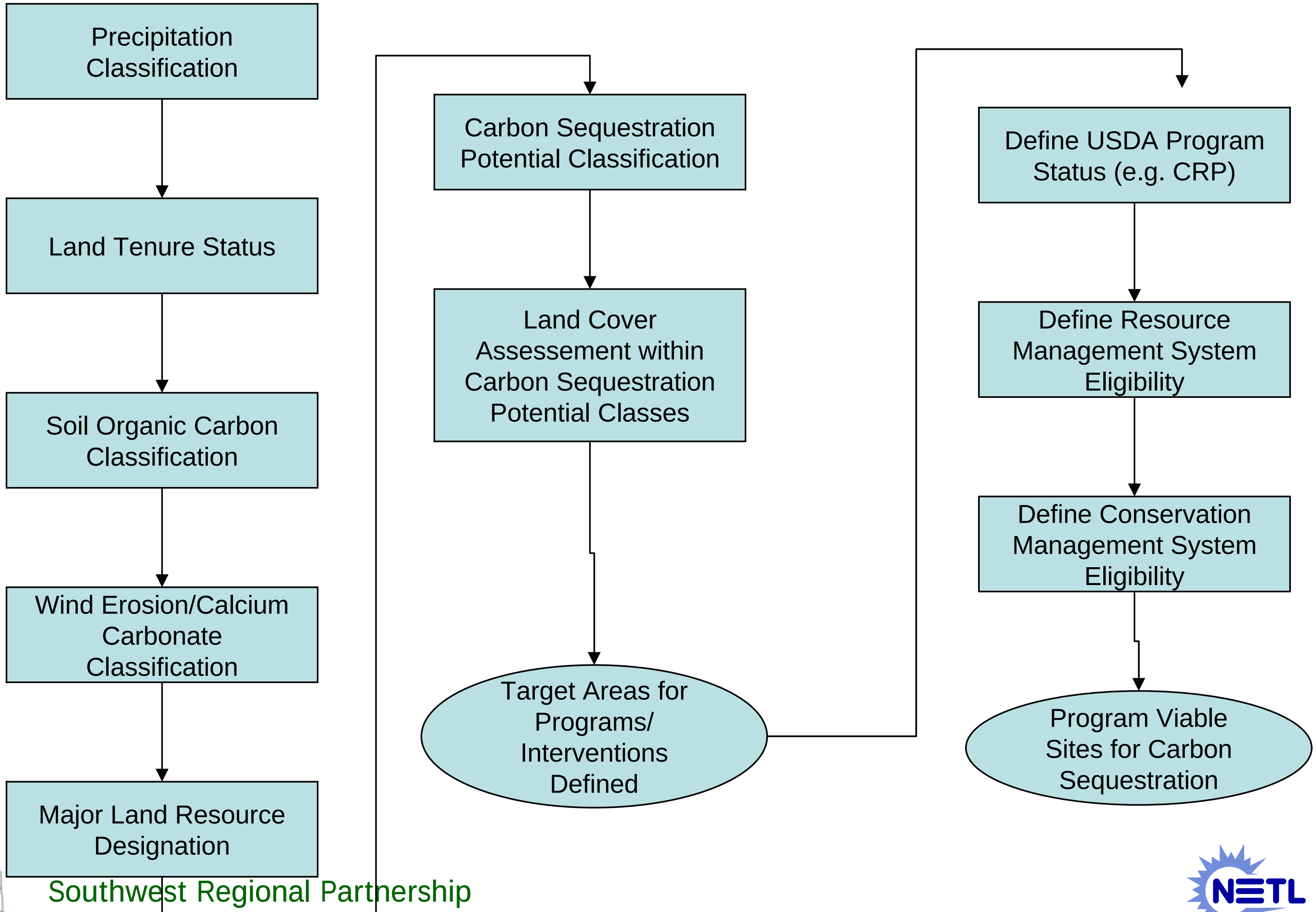
Defining Terrestrial Sequestration Potential

- **GIS analysis to define areas of carbon sequestration potential continues**
  - New Mexico analysis is near completion
  - Other Southwest states are staged and will be completed after final model for New Mexico is completed
  - Once areas are defined, meetings will be held with USDA NRCS personnel to define carbon sequestration programs/interventions for each state

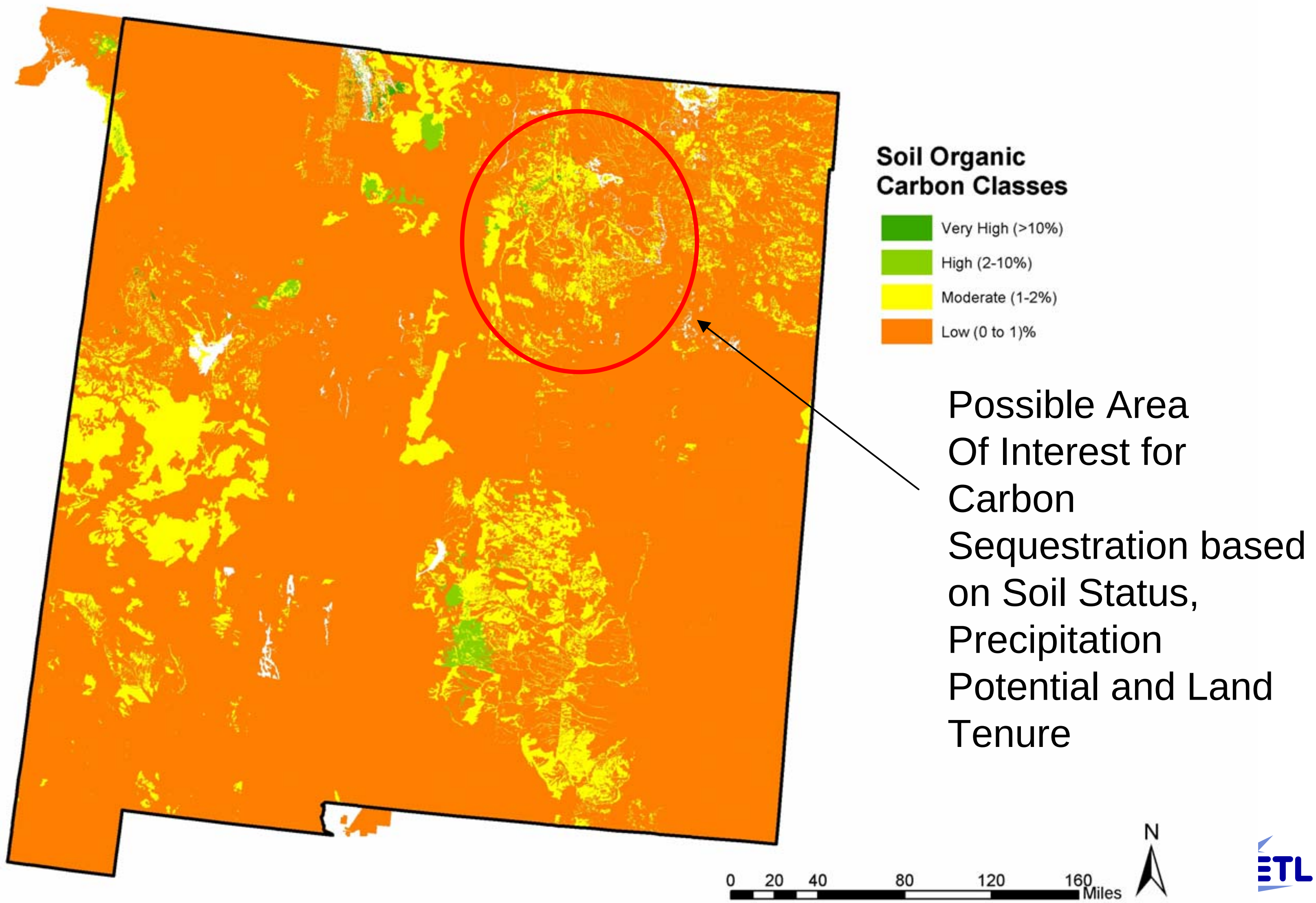


Long-term (1970 to 2000) precipitation data classified into No, Low, Medium and High potential for carbon sequestration

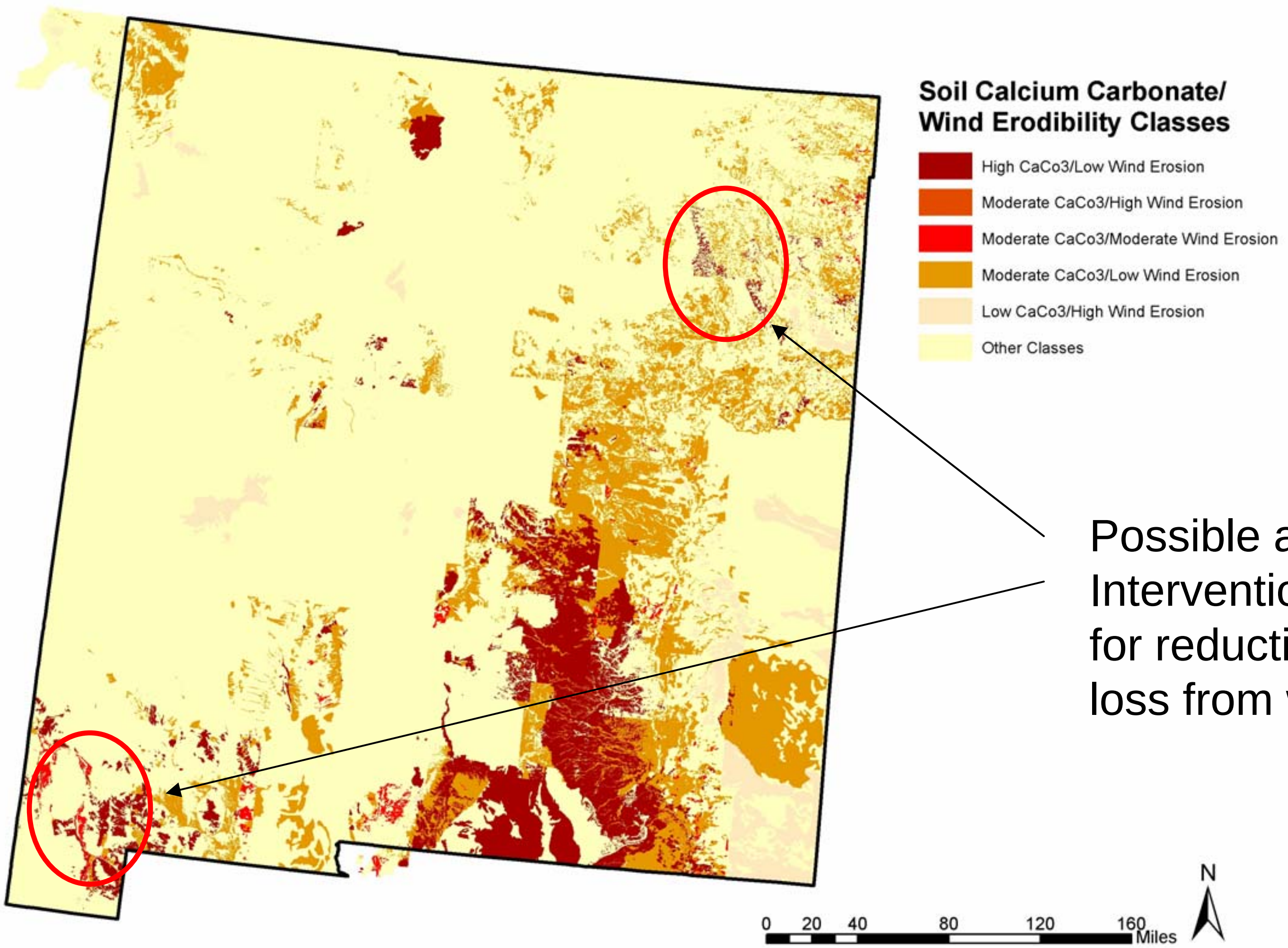
Sequestration Potential Analysis



Soil Organic Carbon Classification



Calcium Carbonate and Wind Erodibility



Possible areas of Intervention programs for reduction of carbon loss from wind erosion.

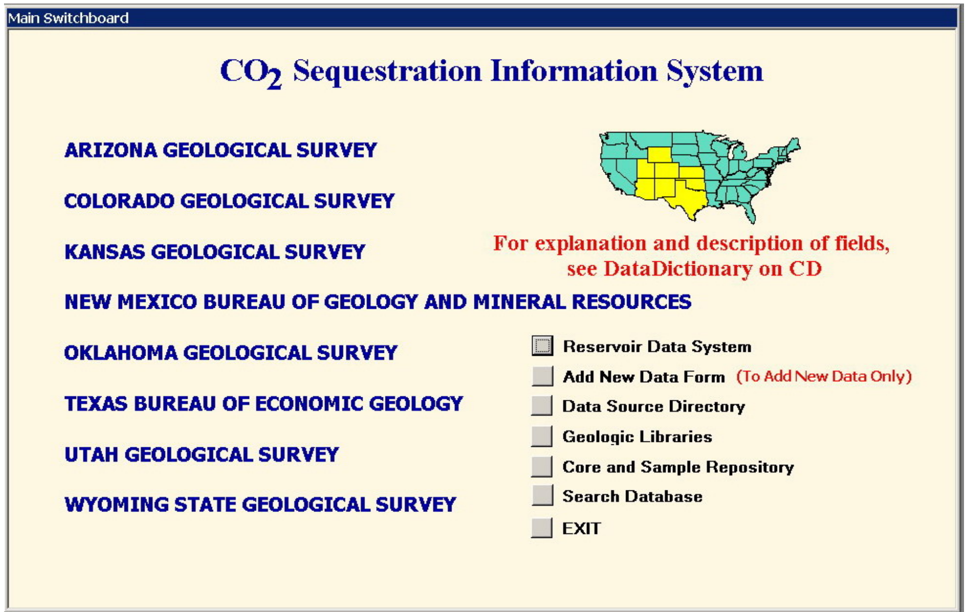
Terrestrial Capacities

Note the first two points, coming to light via "test case":

- Terrestrial sequestration in the Southwest region is **naturally limited by low average annual precipitation** and the interannual variability in precipitation
- Even in systems managed for carbon storage, **wet years followed by a series of dry years** may result in a net carbon flux from the system.
- Increases in soil and vegetation carbon are the result of precipitation-driven carbon assimilation by plants and subsequent storage in stable compounds in the soil or as wood.
- Overcoming natural variability in rain-fed agricultural systems and forests requires increasing acreage for carbon storage region-wide as opposed to intensive management of smaller project-scale areas.

Geologic

First Task for Geologic Data: Modify and Utilize GASIS* Database



*DOE GAS Information System (NETL Version)

www.netl.doe.gov

GASIS database

modified for

- ***Oil and gas reservoirs***
- ***Coalbed methane reservoirs***
- ***Deep saline aquifers***

Main GeoData Collection Agencies

Arizona	**Arizona Geological Survey**
Colorado	**Colorado Geological Survey**
Kansas	**Kansas Geological Survey**
New Mexico	**New Mexico Geological Survey**
Oklahoma	**Oklahoma Geological Survey**
Texas	**Texas BEG**
Utah	**Utah Geological Survey**

Approach

- **Defined approximately 321 attributes for individual fields**
- **Information includes**
  - Field location
  - Geologic attributes
  - Reservoir engineering attributes
- **Screening criteria**

Screening Criteria

- **Production**
  - 1 million barrels of oil production, and /or
  - 10 billion cubic feet of gas production
- **Distance**
  - Sinks within 30 miles of source
- **Depth**
  - Sink deeper than 3,000 ft to maintain CO_2 at supercritical conditions

Overview of Geologic Sinks Data Assembled

Sinks Database Completion Status

	Oil and Gas	Coalbed Methane	Saline Aquifers
AZ	90%	NA	60%
CO	95%	95%	100%
NM	100%	50%	50%
OK	70%	10	10
UT	99%	95%	75%
KS	100	100	100
TX	80	50	50

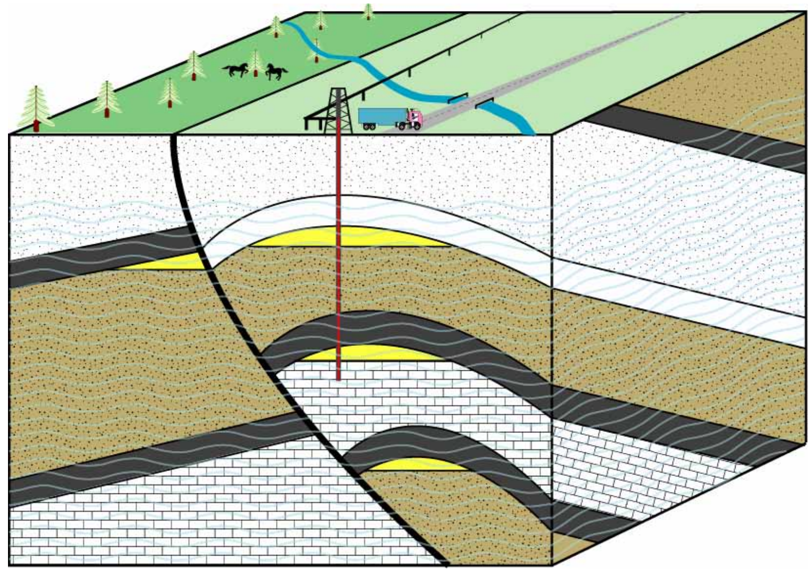
Arizona

- **Data compiled for 14 oil and gas fields**
- **Top 5 fields represent**
  - 21 million barrels of oil
  - 26 billion cubic feet of gas
  - 15 million barrels of water

- **Saline reservoirs – 12 deep and 7 shallower Tertiary; less well defined oil & gas fields**
- **No coalbed methane sequestration opportunities**

New Mexico

- 507 Permian Basin Pools and 80 San Juan Basin (SJB) Pools passed production criteria
- Including four natural CO2 pools
- SJB excellent CBM storage candidate – Burlington Resources' Allison Unit
- Saline reservoir - Morrison Formation of SJB good candidate

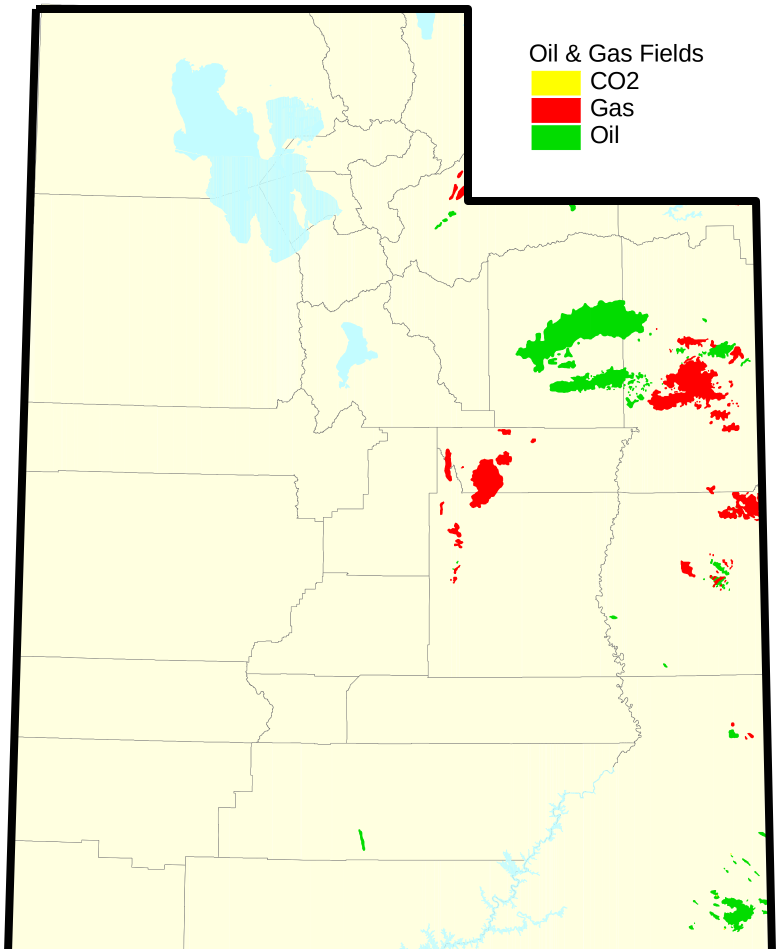


Oklahoma

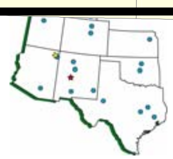
- **Compiled data on more than 2,200 oil and gas fields**
- **612 produced over 1 mmbo; 100+ > 10 mmbo; 26 > 100 mmbo**
- **745 produced over 10 bcf; 11 > 1,000 bcf**
- **Remaining oil-in-place estimated at 42-93 billion barrels**

Utah

Seventy-two Utah Oil and Gas Fields Characterized in Partnership Database



- **Compiled data on 72 oil & gas fields**
- **7 CBM fields included in database**
- **Data on saline aquifers currently being compiled**

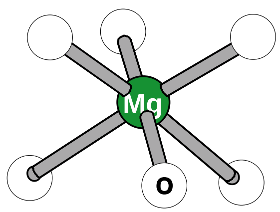


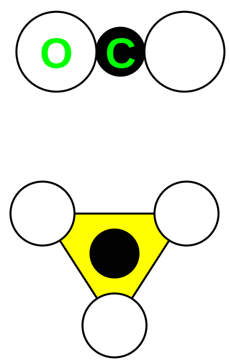
Mineralization-Engineering

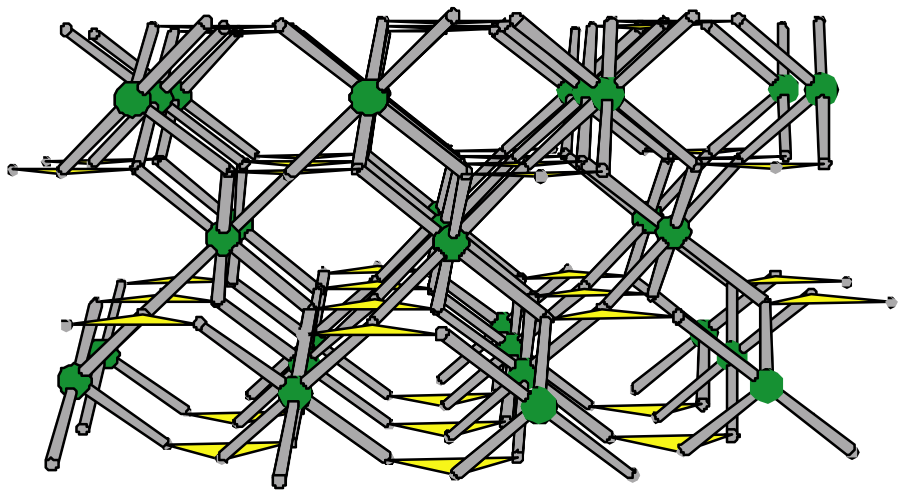
CO_2 Mineralization as an Advanced Storage Concept

Goal: To trap carbon dioxide in an alkali or alkaline-earth metal solid carbonate, rendering it benign and immobile.

metal oxide + carbon dioxide $\Rightarrow$ metal carbonate







Ca- or Mg-carbonate
***e.g.*, calcite or magnesite**

- **Both thermodynamic and kinetic factors must be considered**

CO_2 Mineralization as an Advanced Storage Concept

Natural parallels…

- **weathering reactions**
- **water–CO_2–rock interactions in subsurface environments**
- **biomineralization**

Industrial mineralization…

- **Metals (Ca^{2+}, Mg^{2+}, Fe^{2+}, Na^{+}, K^{+}) derived from combination of sources—e.g., brines, mined ores (*e.g.*, serpentinites), wastes**

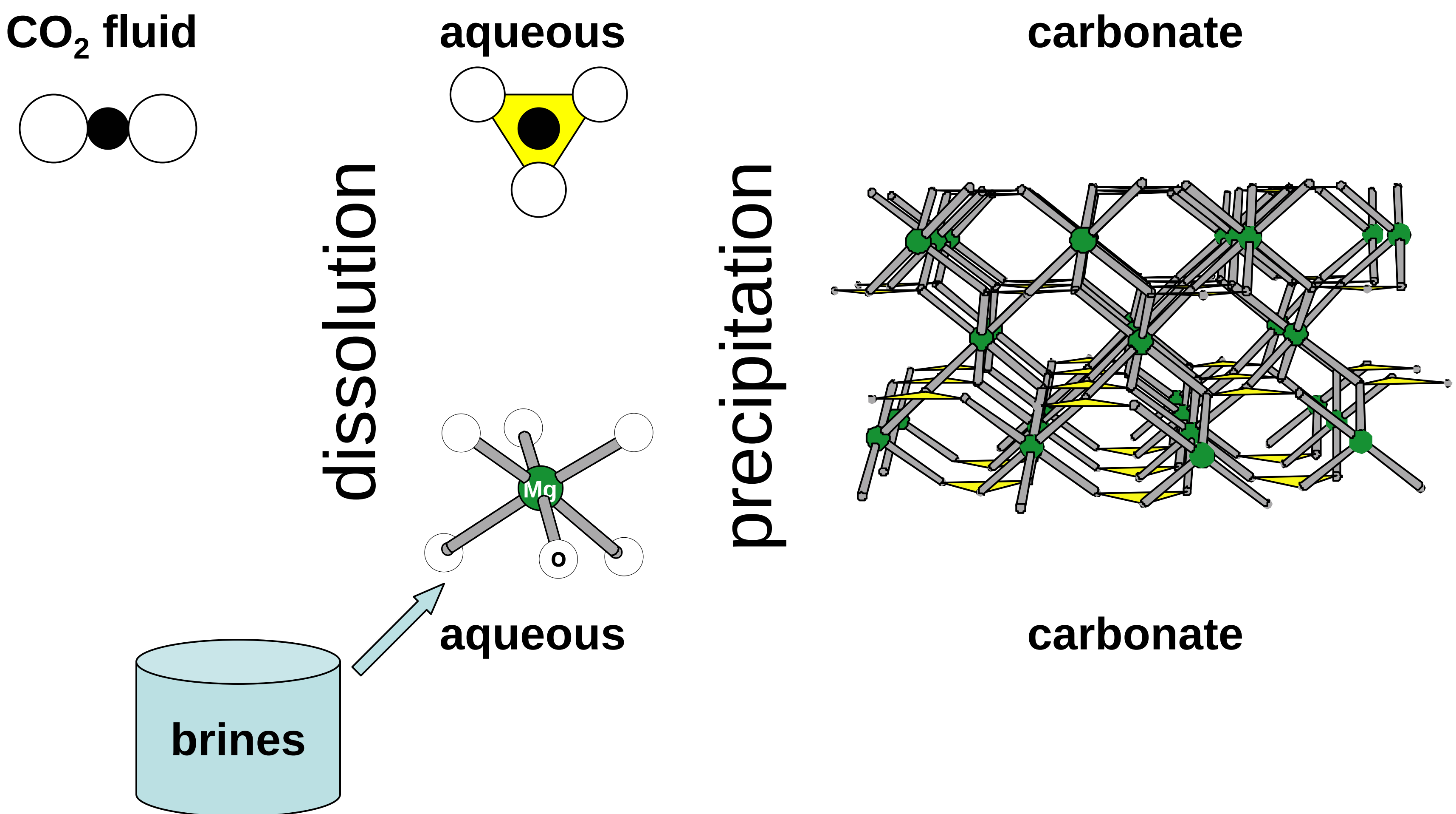
In situ mineralization…

- **CO_2–water–rock interactions in geologic storage reservoirs, leading to complete mineralization or to reduced permeability**

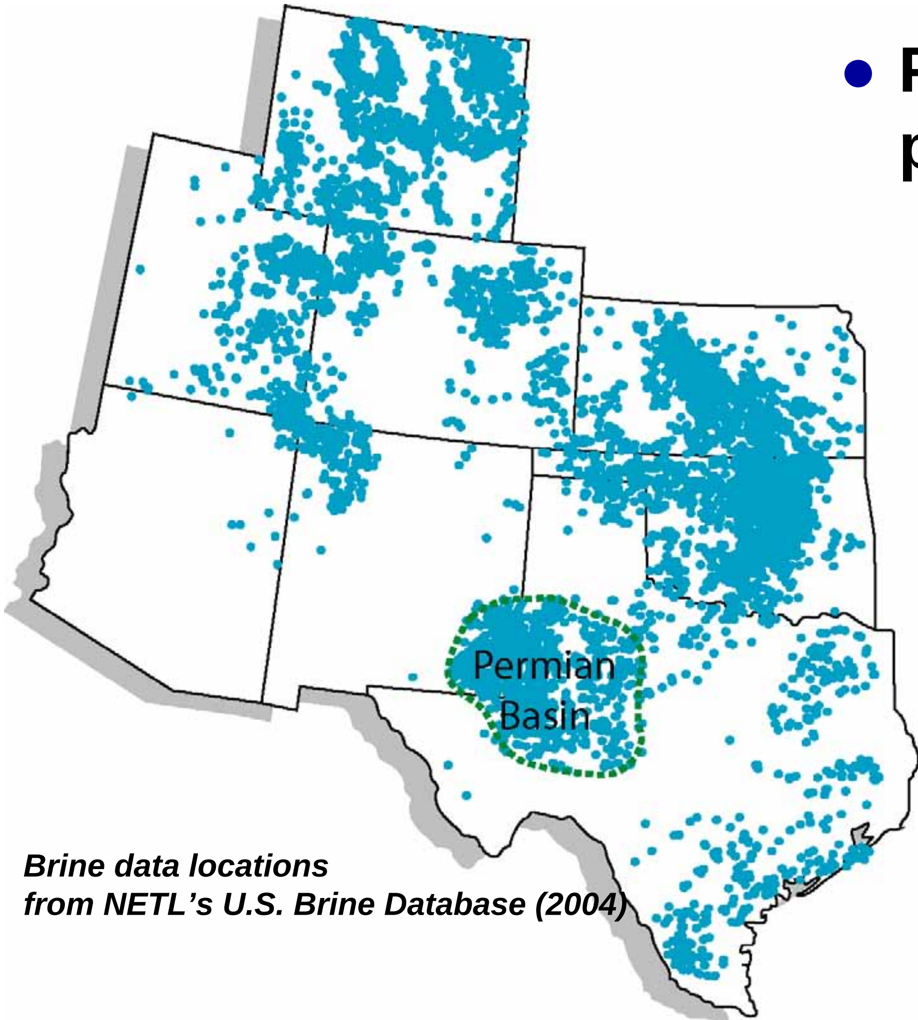
CO_2 Mineralization Relative to Storage Goals

- **Permanency**
  - \+ immobile; relatively low solubilities
- **Environmental acceptability**
  - \+ solid carbonates are typically benign
  - \+ waste conversion
  - – process could involve mining or production operation
- **Verification of amount of C stored**
  - \+ solids can be easily quantified
- **Value added benefit**
  - \+ by products (*e.g.*, Pt, …; water); construction materials
  - \+ waste utilization
- **Economic viability**
  - ? need to identify feasible conversion process(es)

Brines are being evaluated as a potential metal source for CO_2 mineralization.

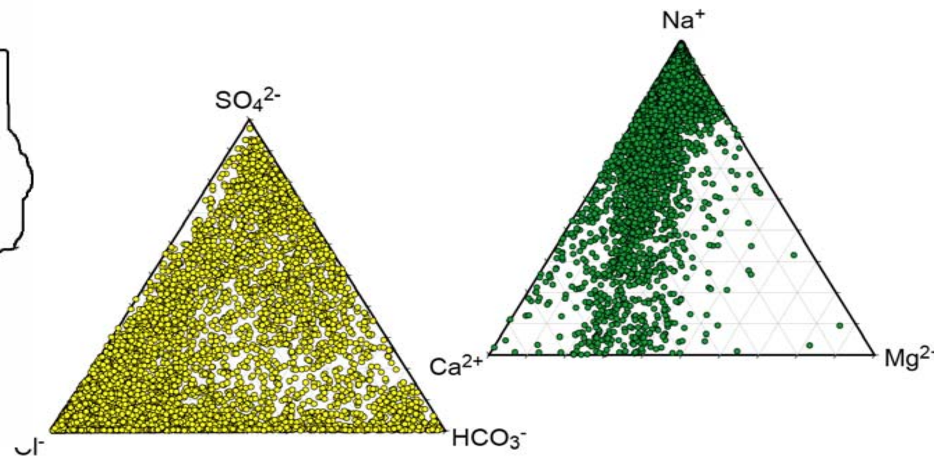


Evaluation of brine mineralization potential is considered by Partnership via chemistry and volume of regional waters.



Brine data locations from NETL's U.S. Brine Database (2004)

- **Produced waters are a particular target**
  - Permian Basin produced waters for 2002 3×10^9 litres
  - ~90% of Permian Basin produced waters currently reinjected
  - ~3.5 $MtCO_2$/yr equivalent of Ca+Mg in Permian Basin produced waters



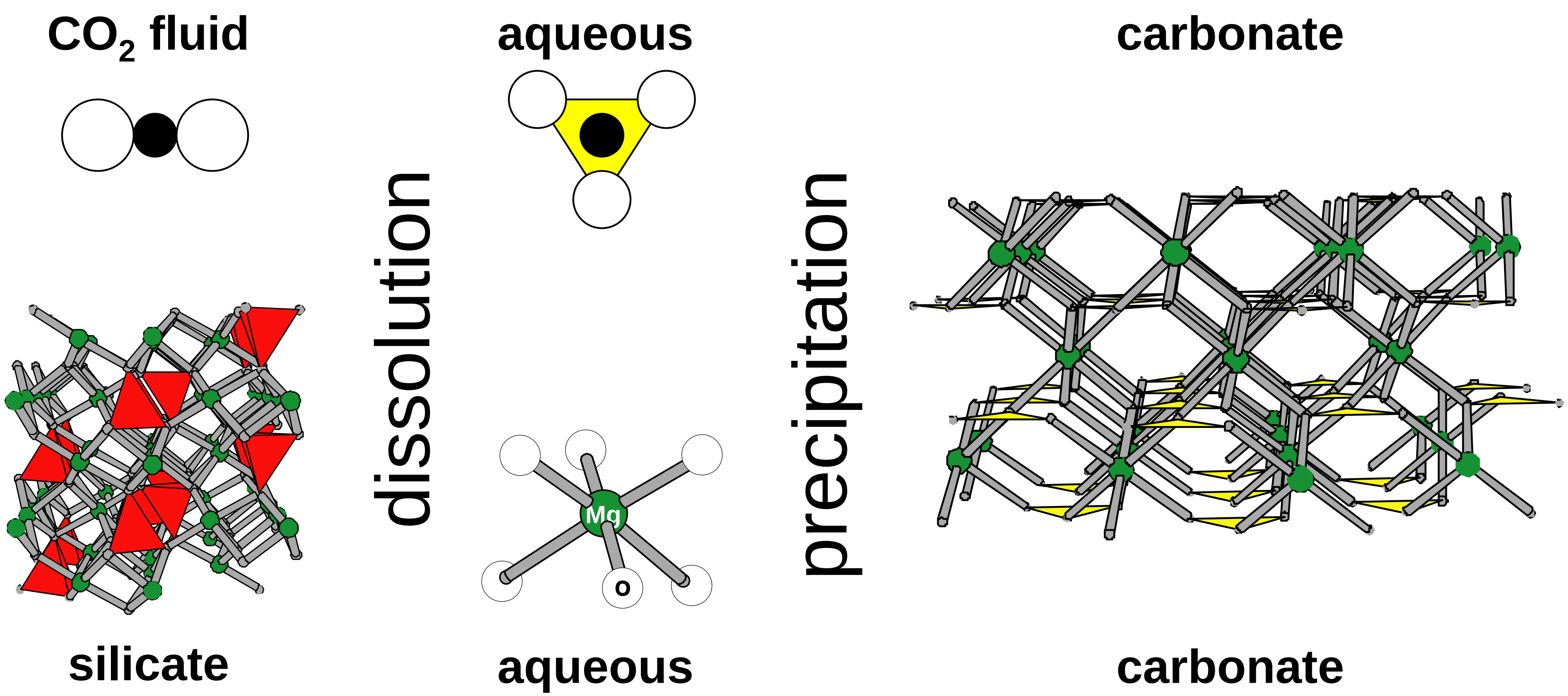
Data from NETL's U.S. Brine Database (2004)

Southwest Regional Partnership on Carbon Sequestration

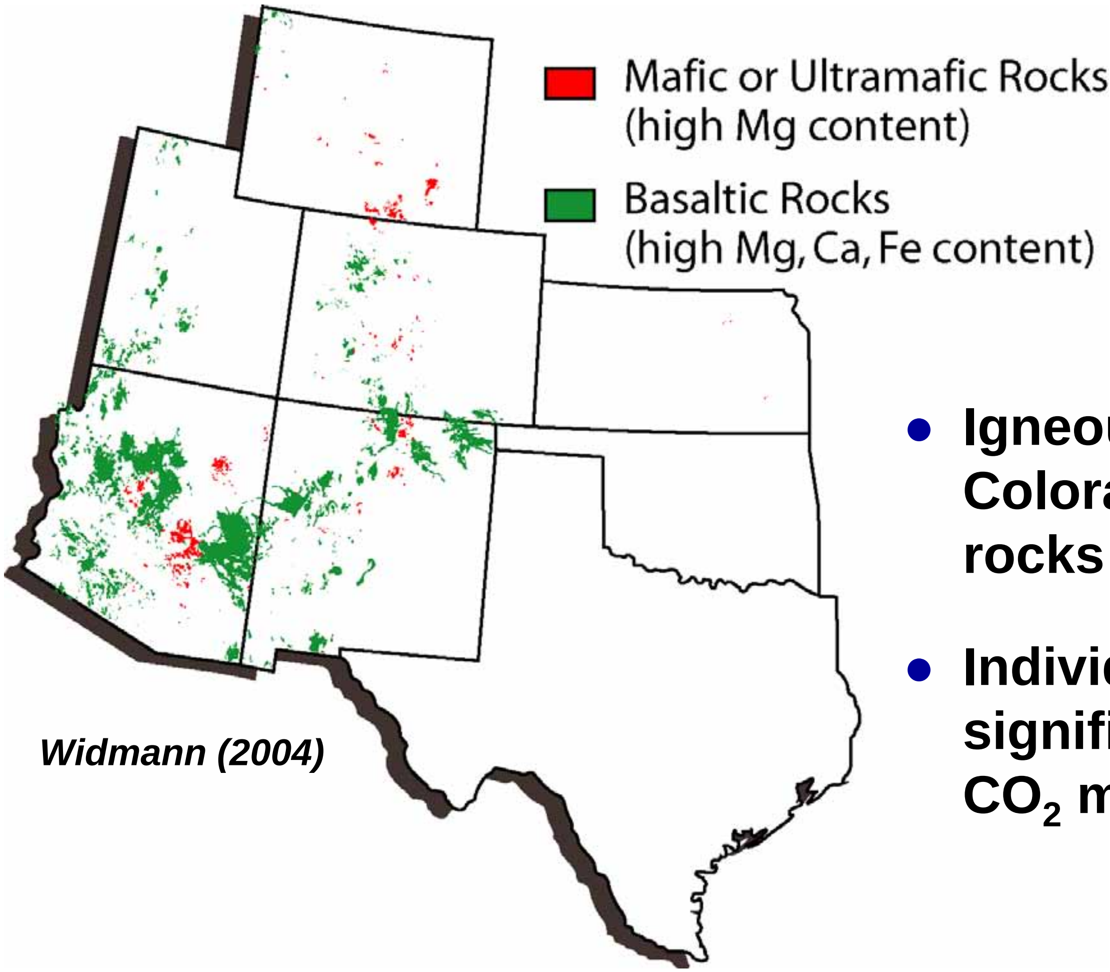
Brine Mineralization: Status of Research Reviewed by Partnership

- **Feasibility demonstrated using HCA II and brine simulants**
  - accelerated hydration of CO_2
  - accelerated precipitation of $CaCO_3$
  - flow-through demonstrated using immobilized HCA II
  - robust relative to industrial levels of SOx, NOx, As, Hg
- **Economic source of enzyme identified**
  - bacterial overexpression of HCA II
  - immobilized HCA II with good activity and low leakage
- **Carbonate successfully precipitated from range of simulants**
  - low cation concentration (~90% Ca ppt in single pass)
  - high cation concentration (~80% TIC ppt in single pass)
- **Possible brine sources under evaluation**
  - produced waters from oil/gas; various waste streams (including from desalination)

Silicate ores are also being considered by the Partnership as a potential metal source for CO_2 mineralization.



Partnership is considering silicate mineralization potential via chemistry and volume of target lithologies.

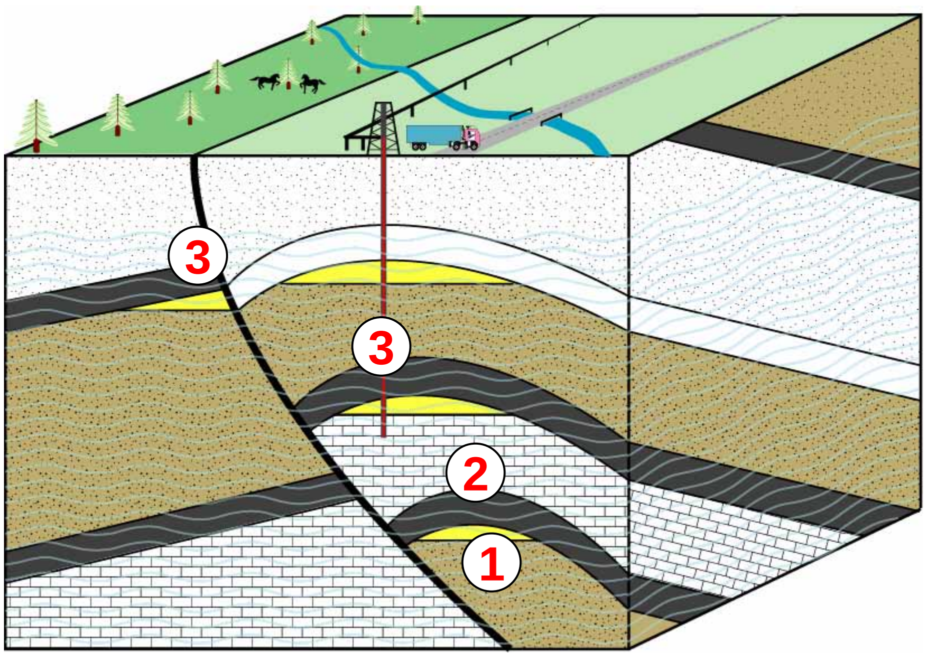


Widmann (2004)

- **Igneous activity associated with Colorado plateau produced rocks enriched in Mg, Ca, and Fe**
- **Individual deposits can be significant regional resources for CO_2 mineralization**

Role of CO_2 Mineralization in Geologic Storage

- complete mineralization
- impact on permeability
- impact on seal integrity



- Fate/distribution of CO_2 plume
  complete mineralization
  vs.
  permeability changes
- Primary seal integrity
- Vulnerable points
  fractures (clays)
  grout (cement)

How are these sinks data evaluated?

Test case analysis, described in subsequent slides, will outline how these sinks data are used, in general.

Summary of Working Groups' Progress

- **Point Sources Group**
- **Separation/Capture/Transportation Group**
- **Sinks/Capacities Group**
- **Regulatory Group**
- **MMV and Risk Assessment Group**
- **Outreach and Public Involvement Group**
- **Database / Information Group**
- **Integrated Assessment Group**

Regulatory Group

- Regulatory requirements for the **application** of CO_2 in oil and gas reservoirs are in place for EOR/EGR
- Work with individual state regulators indicates that specific modifications may be necessary for sequestration, but regulators potential modifications may not be done until sites are specified
- Not all states, including New Mexico, have definitive regulatory constructs for use of natural gas storage reservoirs (case by case)

Regulatory Group

The Southwest Partnership is summarizing specific regulatory constraints and gaps associated with each defined Phase II option site, and this process is elucidating the possible unique aspects that will be required for each state.

Summary of Working Groups' Progress

- Point Sources Group
- Separation/Capture/Transportation Group
- Sinks/Capacities Group
- Regulatory Group
- MMV and Risk Assessment Group
- Outreach and Public Involvement Group
- Database / Information Group
- Integrated Assessment Group

MMV and Risk Assessment Group

Measurement, Monitoring and Verification:

- The Southwest MMV team is developing a comprehensive MMV approach (template for future applications)
- MMV approaches include direct and indirect methods, as developed and described in recent work

Risk Assessment:

- the Southwest Partnership is also developing a comprehensive risk-assessment framework - -
- general approach: systematic methodology for determining risk factors that will be assigned in the integrated assessment analysis

MMV and Risk Assessment Group

The Partnership is developing specific MMV and risk-assessment plans for each defined Phase II option site, and this process is elucidating aspects of approaches that will likely be required for future long-term sequestration options in the region.

Summary of Working Groups' Progress

- Point Sources Group
- Separation/Capture/Transportation Group
- Sinks/Capacities Group
- Regulatory Group
- MMV and Risk Assessment Group
- Outreach and Public Involvement Group
- Database / Information Group
- Integrated Assessment Group

Outreach and Public Involvement GOALS

Identify—

current public opinion & knowledge of carbon sequestration.

Enable—

public to evaluate costs and benefits associated with carbon sequestration.

Objectives

- Identify & respond to needs, fears, & desires on carbon sequestration.
- Inform about requirements & strategies for successful carbon sequestration.
- Involve in discovery of opportunities.
- Enable negotiation of mutual benefits.

Multiple Stakeholders

- Industry
- Environmental groups
- General public
- Governments
- Partnership members

Communication Techniques

- Formal presentations
  - requirements, options, opportunities

- Learning activities
  - mediated modeling

- Process training
  - communication skills

Tools

- Web page (dissemination, dialogue)
  - information transmission
  - electronic interaction (limited)

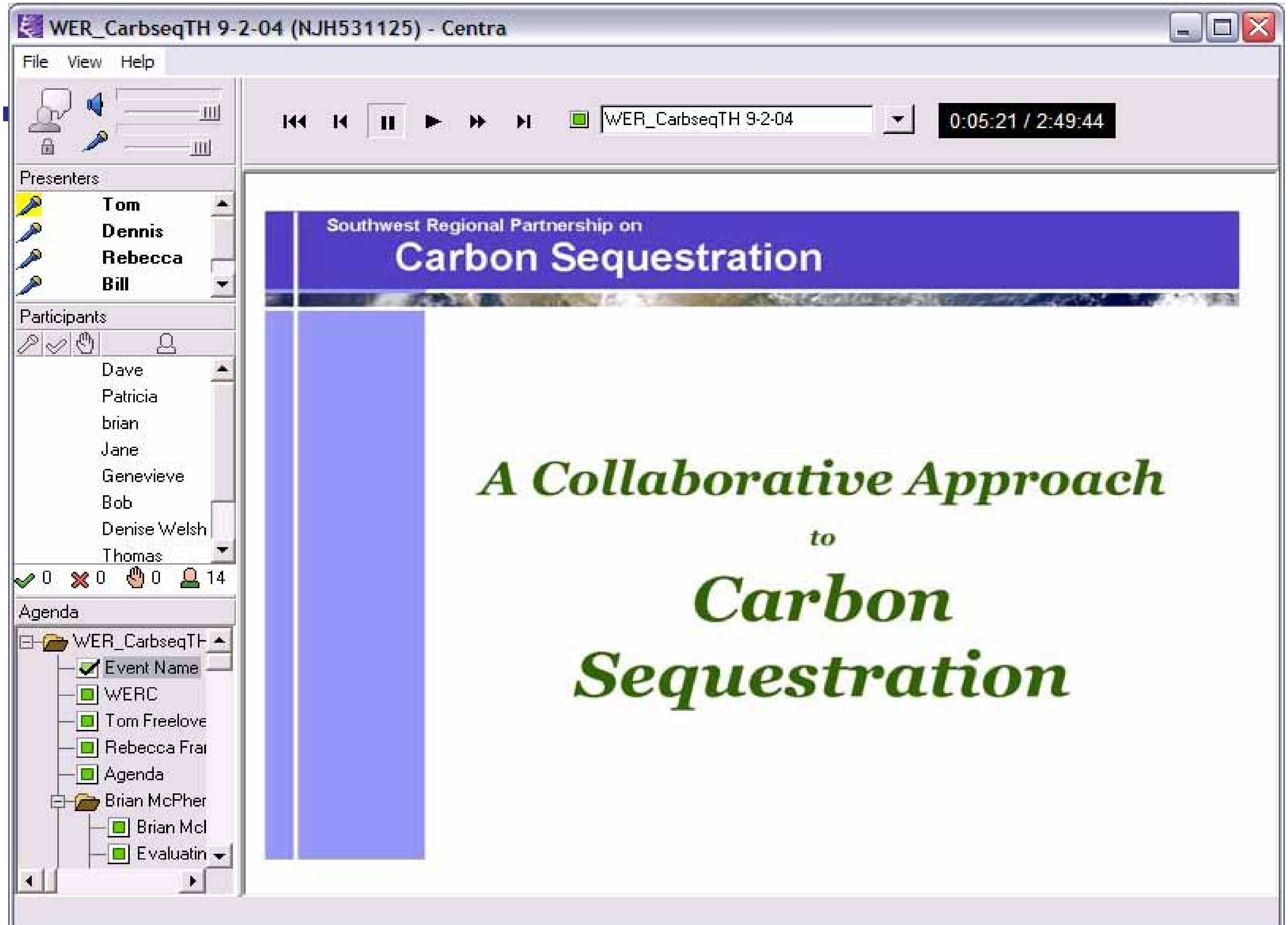
Tools

- Web page (dissemination, dialogue)
- **Information packets distributed**
  - **Information dissemination**

Tools

- Web page (dissemination, dialogue)
- Information packet (dissemination)

- **Townhall meetings (dissemination, dialogue)**
  - **information transmission**
  - **electronic interaction (regional)**
  - **in-person interaction (local)**


WER_CarbseqTH 9-2-04 (NJH531125) - Centra
File
View
Help
WER_CarbseqTH 9-2-04
0:05:21 / 2:49:44
Presenters
Tom
Dennis
Rebecca
Bill
Participants
Dave
Patricia
brian
Jane
Genevieve
Bob
Denise Welsh
Thomas
0
0
0
14
Agenda
WER_CarbseqTH
Event Name
WERC
Tom Freelove
Rebecca Frai
Agenda
Brian McPher
Brian McI
Evaluatin
Southwest Regional Partnership on
Carbon Sequestration
A Collaborative Approach
to
Carbon
Sequestration

Benefits of Web-Cast Technology

- “Live” interaction/discussion among industry representatives across multiple states.
- A common theme is presented to each state.
- Provides greater discussion of regional specific issues/concerns regarding sequestration technologies and potential sites for deployment.
- Encourages stronger interaction from industries operating in multiple states.
- Background information and presentations were compiled and distributed to all participants.
- Minimized overall expense of hosting multiple town hall meetings.

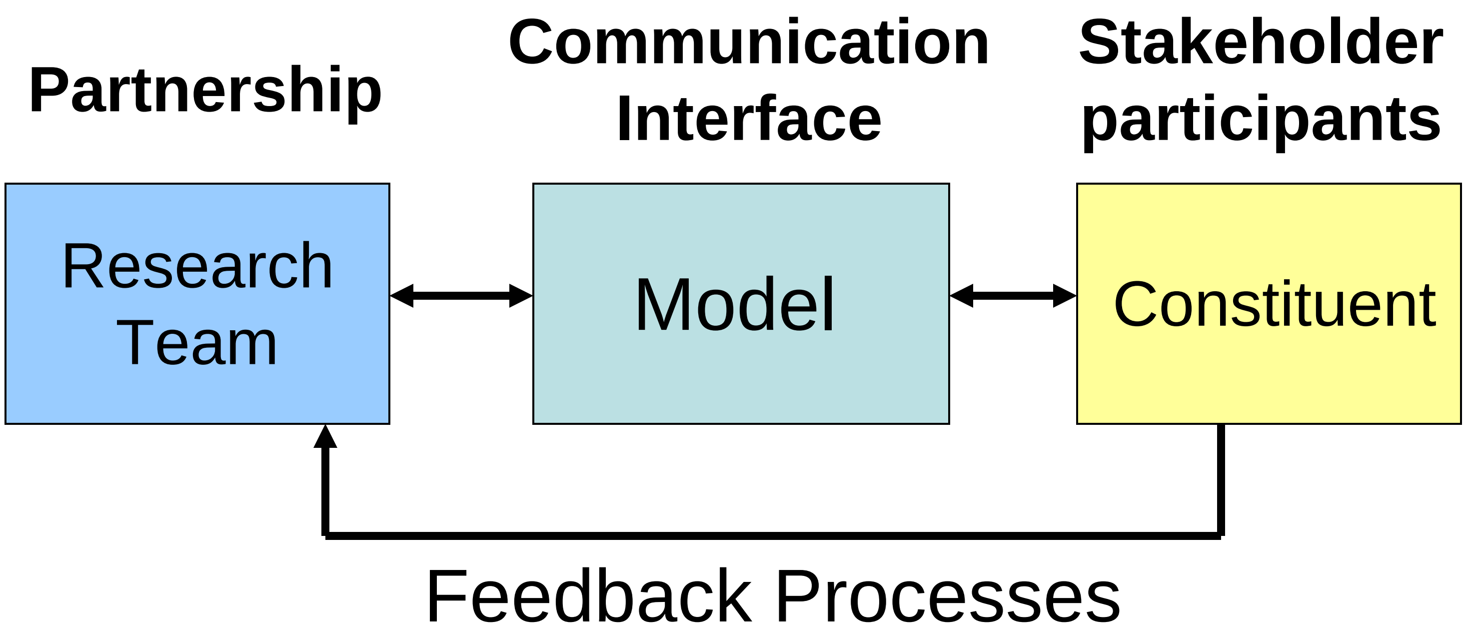
Focus Group Interaction

- The outreach focus group has held on-going web-cast meetings to maintain monthly dialogues.
- The technology allows for “live” sharing of files.
- The technology facilitates stronger interaction among focus group members.
- The technology reduces overall travel expenses.

Tools

- Web page (dissemination, dialogue)
- Information packet (dissemination)
- Townhall meetings (dissemination, dialogue)
- **Mediated modeling workshops (dialogue, dissemination)**
  - **in-person interaction**
  - **information transmission**
  - **Participation by “Industry Advisory Panel”**

Mediated Modeling - dialogue



Challenges

- Engaging specific stakeholder groups
  - environmental interests are site specific
  - primary participants are industry as many other stakeholders face more pressing issues
  - disengaged stakeholders do not see immediate benefit
  - time restrictions (people lack the time to be involved)
  - number of States involved and travel distance

Summary of Working Groups' Progress

- Point Sources Group
- Separation/Capture/Transportation Group
- Sinks/Capacities Group
- Regulatory Group
- MMV and Risk Assessment Group
- Outreach and Public Involvement Group
- Database / Information Group
- Integrated Assessment Group

Database Status

- **Most layers are completed and are in the database or will be put in soon:**
  - Base Layers (roads, terrain, boundaries, elevation, etc.)
  - Land Ownership
  - Terrestrial Sinks

- **Others are in work:**
  - Geologic Sinks
  - Powerplants (near completion)

- **Most layers that are in work have preliminary versions in the database at present**

Geologic Sinks

- **The geologic sinks have been the largest hurdle.**
- **Each state has a somewhat different way of representing the formations and recording their properties.**
- **The GASIS database has been used as a common source of data which can be tied to oil and gas field layers.**
- **The attributes of the oil and gas fields have finally been narrowed down to a core set that will be used in selecting the most viable candidates.**

Coordination with Other Partnerships

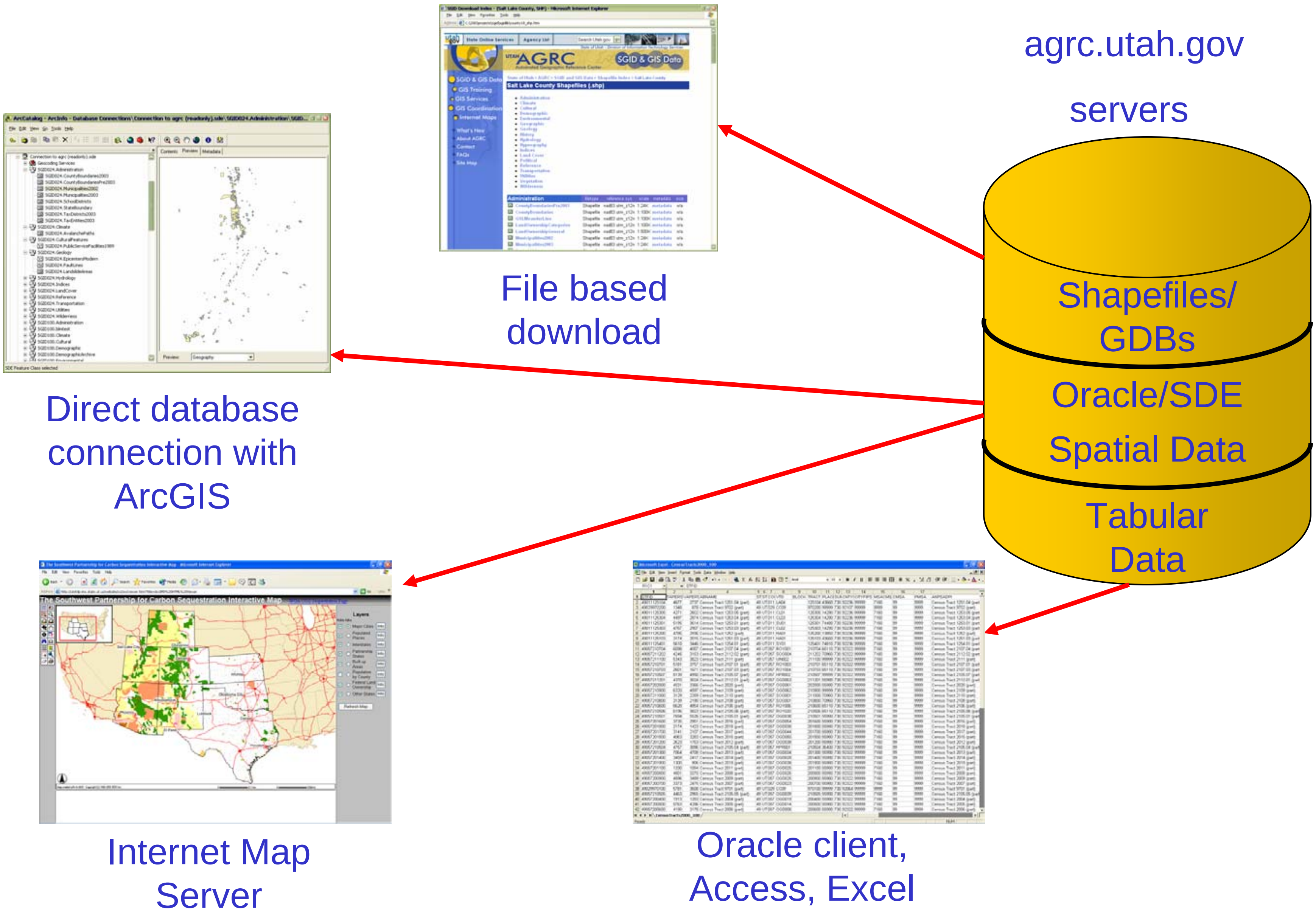
- **Different approaches among the partnerships result in different data needs.**

- **Data for Arizona, Wyoming, and Texas will be shared between the partnerships as much as possible.**

Cooperation with NATCARB

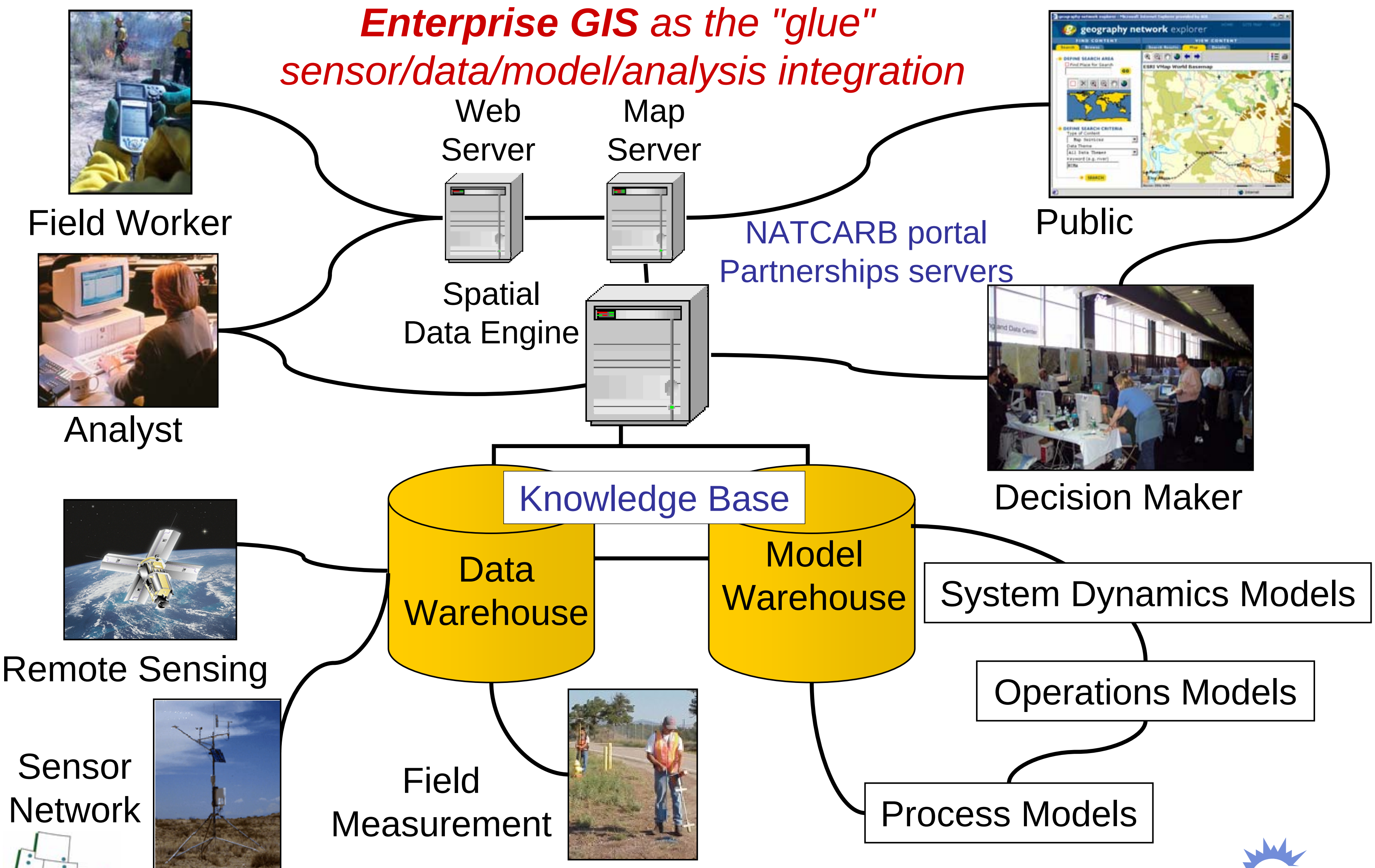
- **At this time Point sources are being served to the NATCARB IMS site.**
- **More layers from the Southwest partnership will be added to the NATCARB site as they are finalized.**

Access to the database

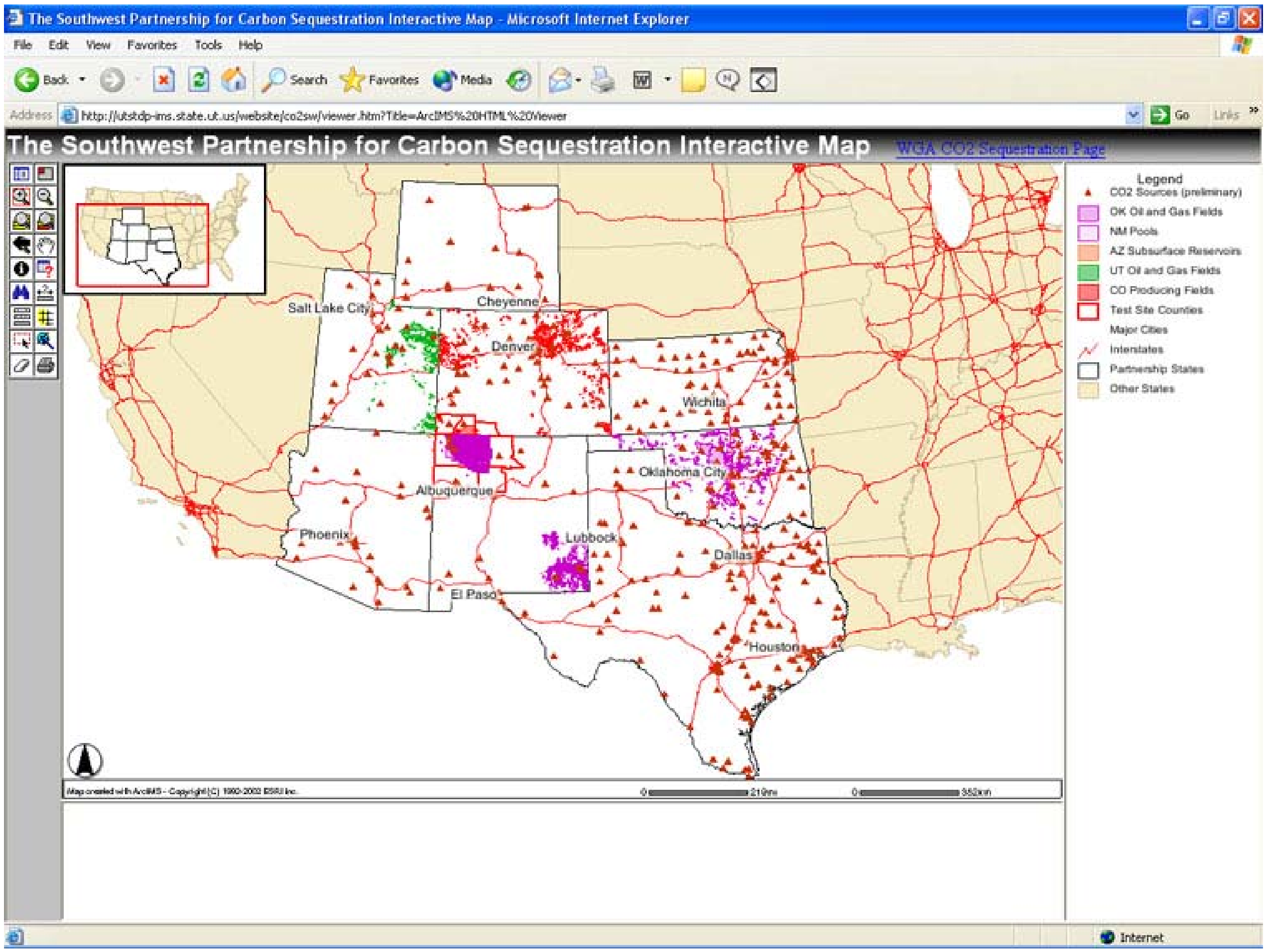


What is AT or NEAR Location X?

Carbon Cyberinfrastructure



Southwest Partnership Internet Map



- Includes all layers in the database at present.
- Provides some basic analysis functions.
- Serves as a communication tool within the partnership.
- Also serves as a public outreach tool.

Summary of Working Groups' Progress

- Point Sources Group
- Separation/Capture/Transportation Group
- Sinks/Capacities Group
- Regulatory Group
- MMV and Risk Assessment Group
- Outreach and Public Involvement Group
- Database / Information Group
- Integrated Assessment Group

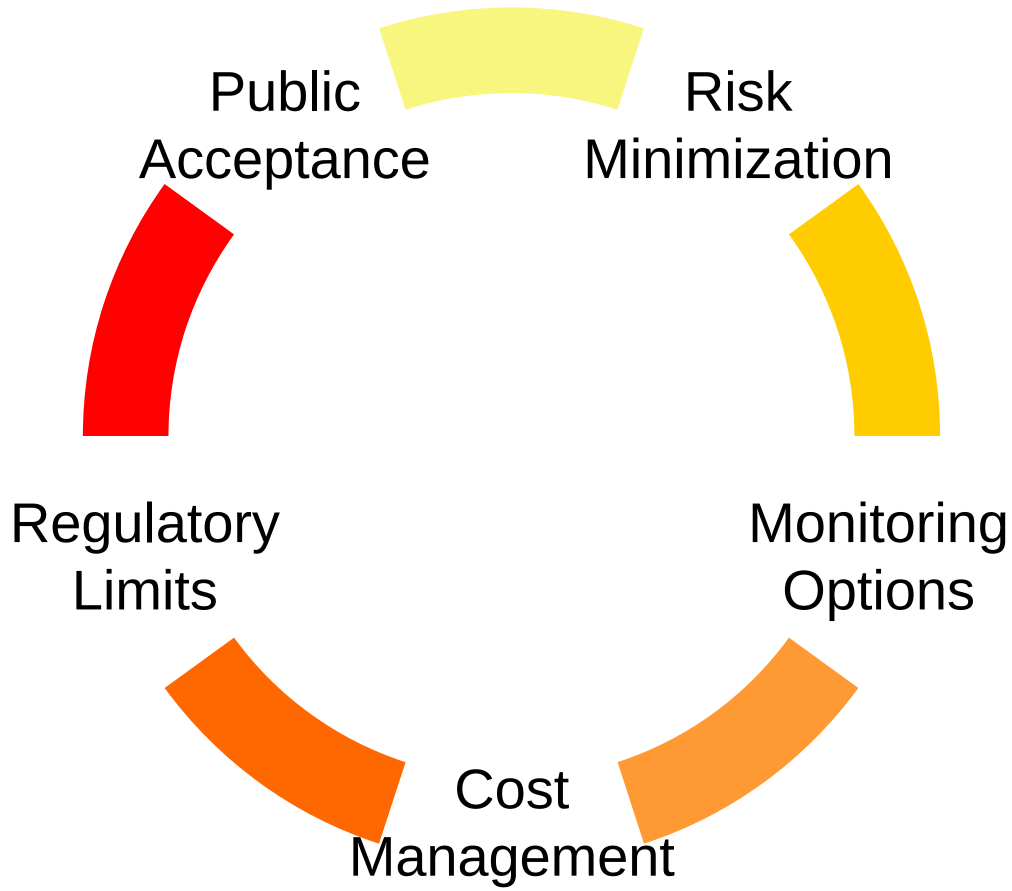
Integrated Assessment Committee Objectives

- **Provide a model to compare quantitatively alternative sequestration technologies in terms of:**
  - Costs
  - Environmental risks
  - Monitoring, verification requirements
  - Regulatory, permitting constraints
- **Establish an integrated assessment framework for non-model elements (e.g., non- or semi-quantitative aspects such as public involvement)**

Integrated Assessment Model Characteristics

- **Dynamic simulation framework**
- **Track annually in southwest region to 2025:**
  - Economic and population growth
  - Energy consumption
  - CO_2 emissions
  - CO_2 sequestration opportunities, potential results
  - Life cycle costs of capture, separation, transportation, and sequestration of CO_2
- **Link GIS database of CO_2 sources and sinks to the economic/population/energy elements**

Other Screening Criteria



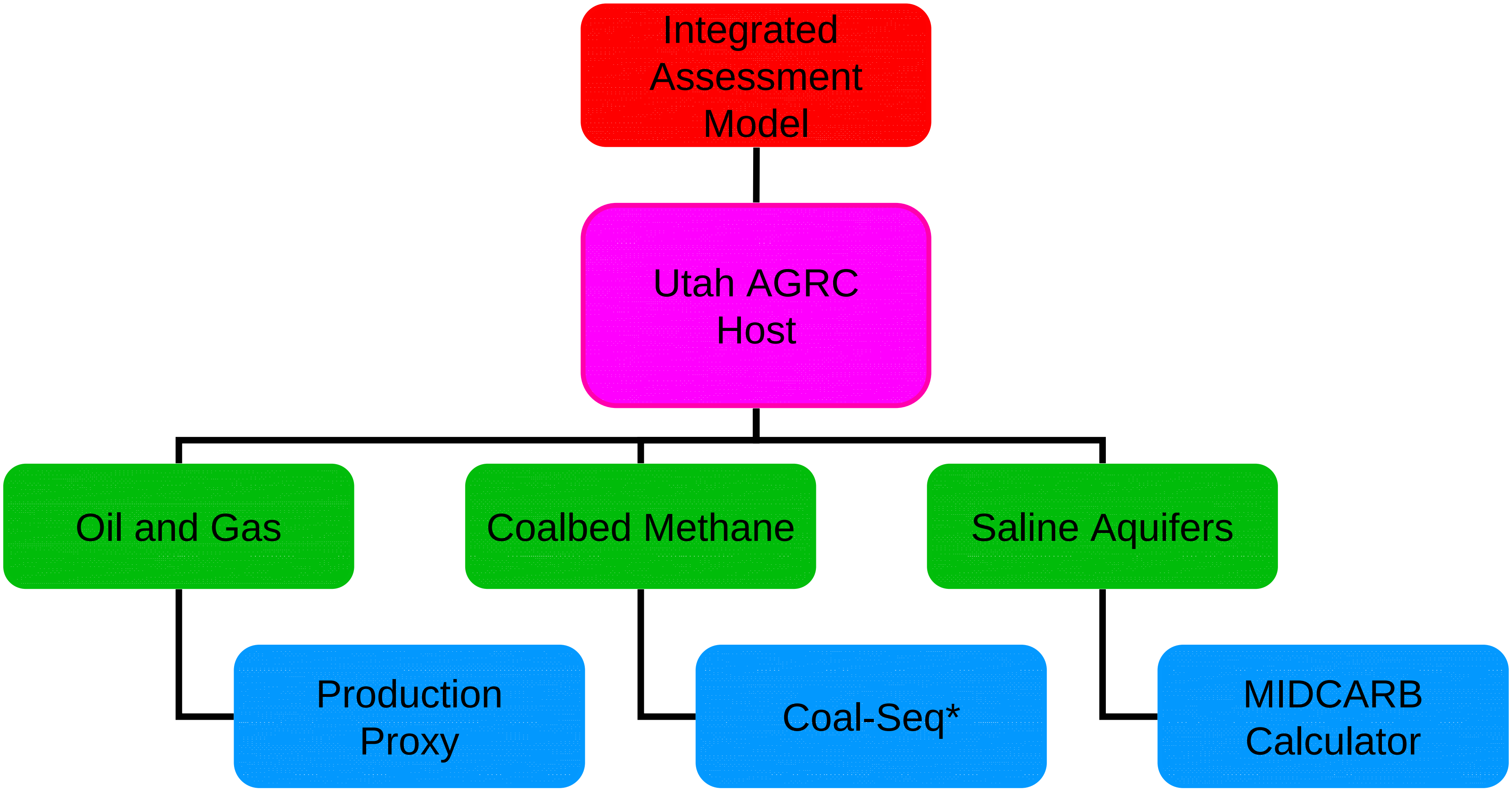
Quantifying These Criteria For Model

Cost Management	Kinder Morgan – Existing CO_2 floods / pipeline infrastructure GTI – Separation and capture technology
Regulatory Limits	IOGCC surveys / analysis
Public Acceptance	Web-based town hall meetings Workshops with model access
Risk Minimization	In progress
Monitoring Options	In progress

Integrated Assessment Model Characteristics

- **The economic/population/energy modeling framework is completed**
- **The CO2 source/sink module is under development**
- **The CO2 source/sink module accounts for:**
  - CO2 capture, separation, transport, and disposal costs
  - rank the source-to-sink costs for different combinations of CO2 sources and sinks

Evaluating Capacity / Injectivity



Evaluating Capacity / Injectivity

- Only applicable to oil and gas reservoirs
- Cumulative fluid production indicates reservoir volume available for storage
- Peak or average fluid production established upper limit for CO_2 injectivity

Integrated Assessment Model

Utah AGRC Host

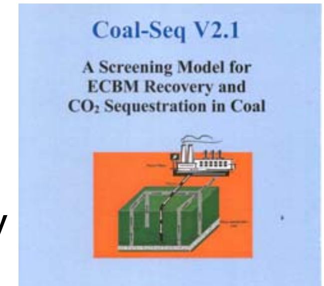
Oil and Gas | Coalbed Methane | Saline Aquifers

Production Proxy | Coal-Seq* | MIDCARB Calculator

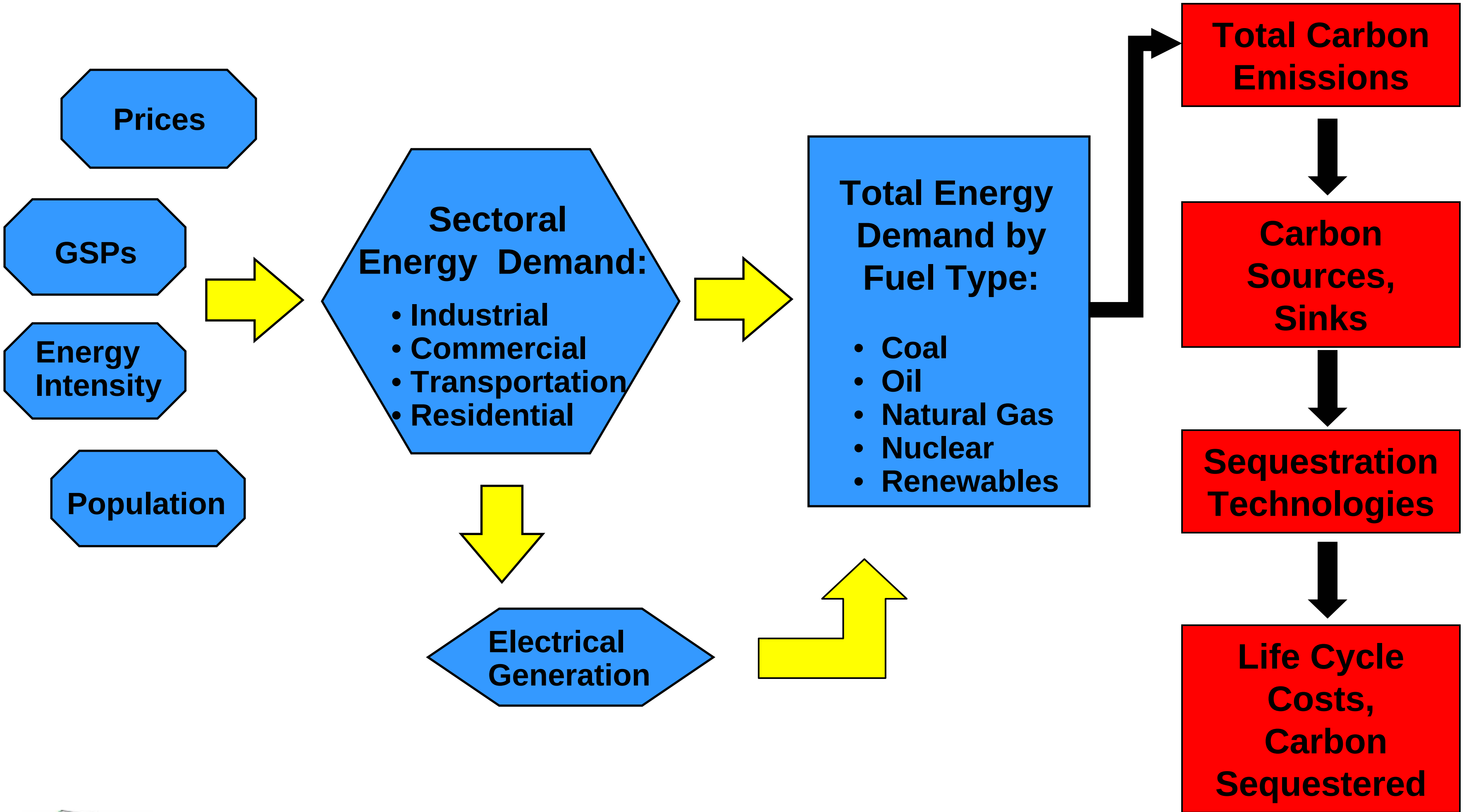
$^*CO_2/CH_4$ Ratio 4 to 10

Key parameters

- coal rank
- thickness
- permeability



Integrated Assessment Model
Basic Structure



Integrated Assessment Model Application

- **System model will allow exploration of "what if" scenarios for alternative:**
  - Technologies
  - Sequestration sites
  - Regional economic, energy conditions
  - Time frames for sequestration
- **Support candidate site and technology selection process**
- **Help in providing public outreach and education**

Integrated Assessment Model: Next Steps

- **Finish carbon flow module**
- **Establish monitoring, verification elements**
- **Link the sources/sinks module to the economic/population/energy module**
- **Interact again with workshop and web-based model demonstration participants**
  - Obtain reactions to prototype
  - Develop metrics besides cost
  - Initiate public education process
- **Expand the test case model to the whole Southwest region**

Sequence of Integrated Assessment Analyses

1. Test case area

- to identify “gaps” in our analyses and refine/improve all aspects

2. Definitive Phase II Options

- following the test case, will use refined assessment package to provide equitable comparison of Phase II options

3. Rest of region

- Analysis of all regional options and sites, so optimum choices via capacities, economic factors, potential risks, applicable regulatory policies, etc., are known, available, and ready for use.

Outline

- **Overview of Region and Partners**
- **Overview of Partnership Organization and Management**
- **Summary of Tasks and Working Group Efforts**
- **Southwest "Test Case" - Prototype for Final Analyses**
- **Summary of Phase II Pilot Options**

Southwest “Test Case” Analysis

Southwest “Test Case” - a Prototype Example of the Partnership’s Ultimate Analysis

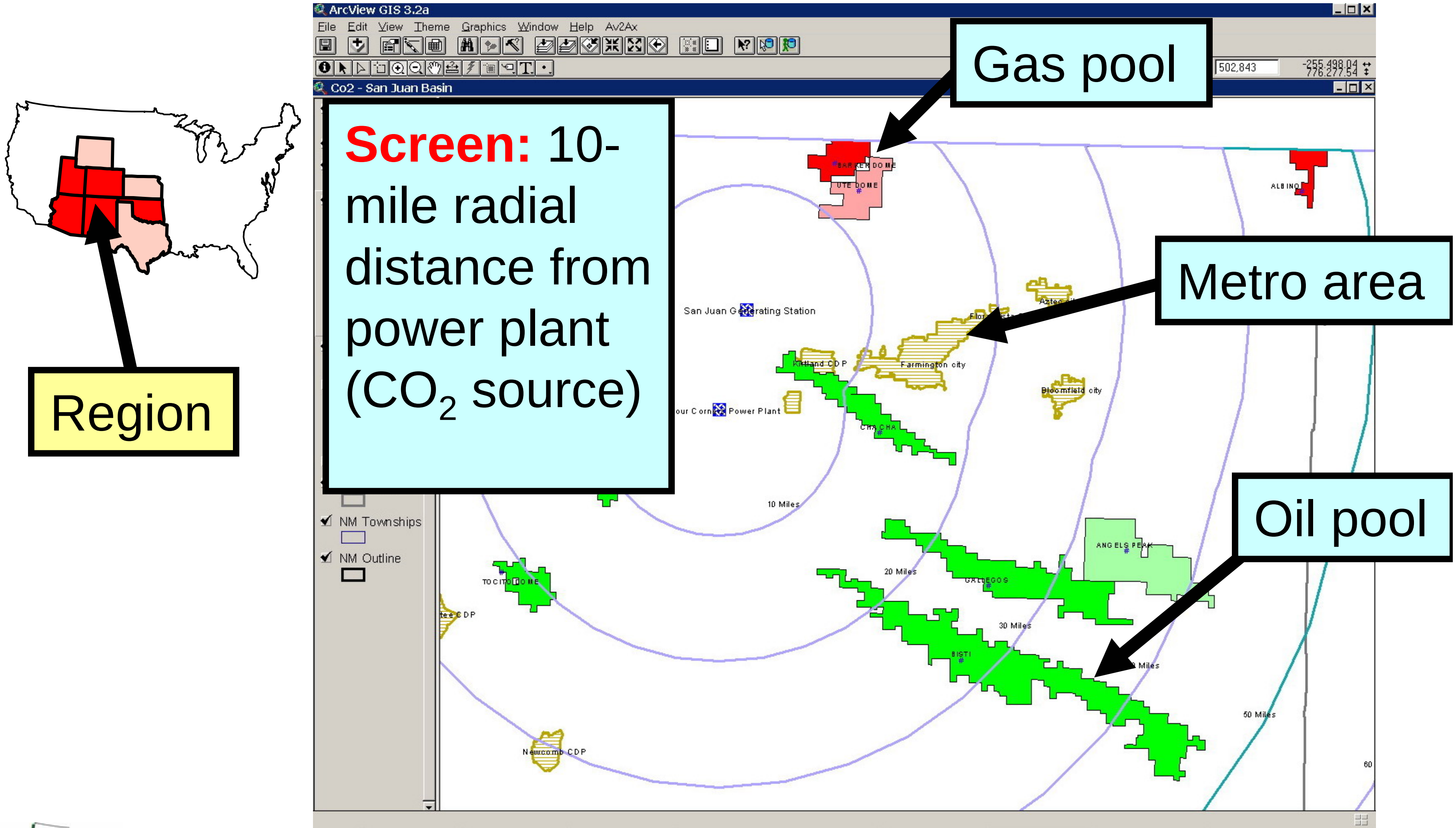
Resulting template will permit equitable quantitative comparison **and ranking** of all sequestration options and associated sites.

Southwest "Test Case" Analysis

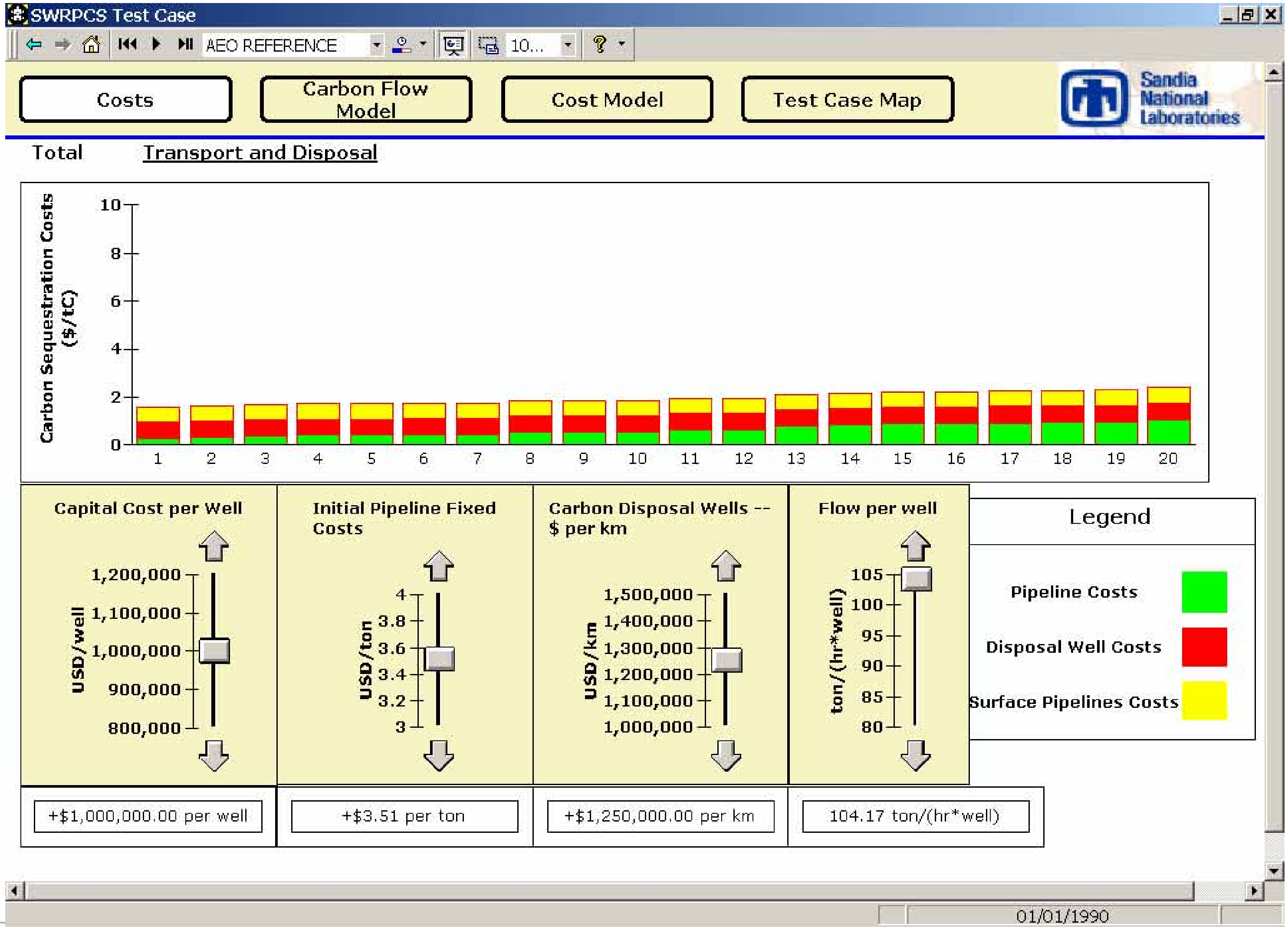
- **Initial test case study**
  - San Juan Basin region in CO and NM
  - 5 power plants
  - Select underground storage sites
    - ≥ 3000 feet deep
    - Have desirable geological characteristics (e.g., low chance of CO_2 escaping into surrounding strata or the surface)
    - Within a certain distance from the power plant(s)
- **Refine the integrated assessment model**
- **Involved public through two workshops and two web-based model demonstrations**

Integrated Assessment Model: Front Page

“Test Case” Area Map



Integrated Assessment Model: Costs



Outline

- **Overview of Region and Partners**
- **Overview of Partnership Organization and Management**
- **Summary of Tasks and Working Group Efforts**
- **Southwest “Test Case” - Prototype for Final Analyses**
- **Summary of Phase II Pilot Options**

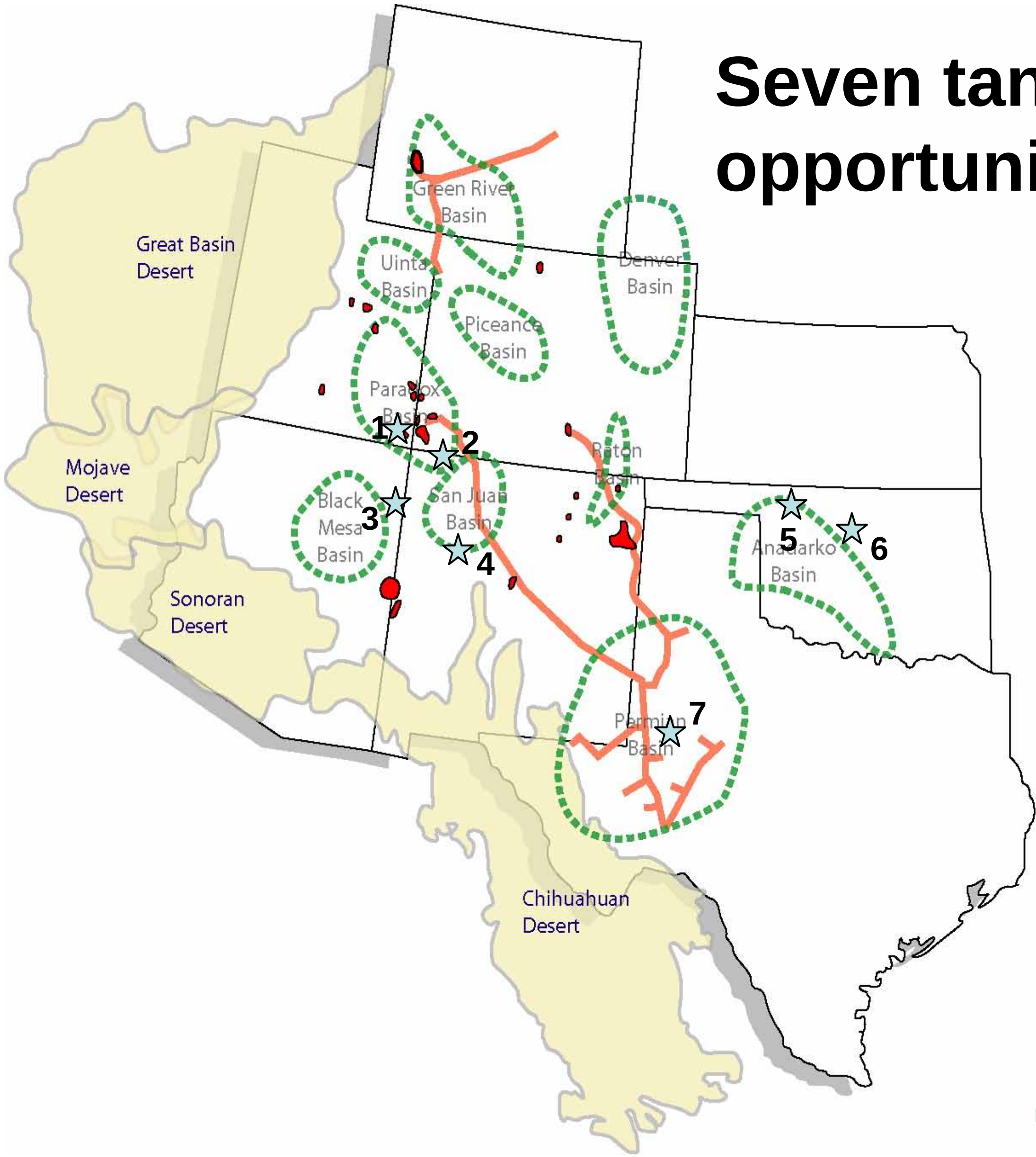
Phase II Tentative Plans

- One or two geologic pilots
  - EOR and deep saline options
  - separation/capture options
  - take advantage of extensive pipeline infrastructure in region
  - MMV and risk assessment framework priority

- One “secondary” terrestrial pilot

- Tentative collaborative projects with Big Sky and WestCarb

Top Phase II Opportunities



Seven tangible geologic opportunities in three areas:

- Four Corners Area
- Northern Oklahoma
- Permian Basin

"Secondary" terrestrial pilot options exist throughout region

Four Corners Area

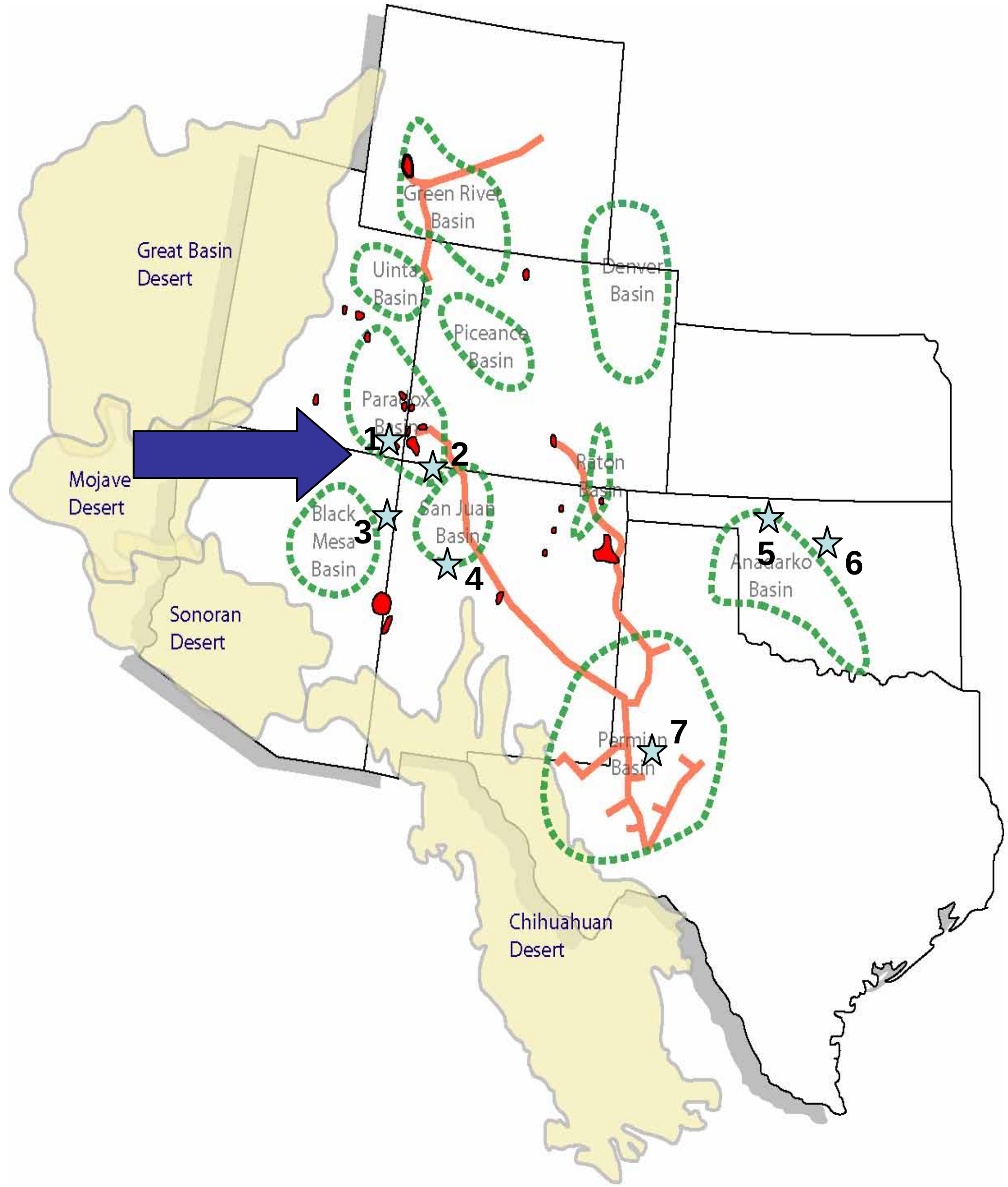
Aneth Oil/Gas Field, Utah:

- Coupled EOR/sequestration
- Numerous geologic units are targets

Industry partners <u>in discussions</u> are:

- Navajo Oil and Gas Company (recently acquired significant property from ExxonMobil)

  (Navajo Nation is a Southwest Partner)
- ExxonMobil
- Kinder Morgan

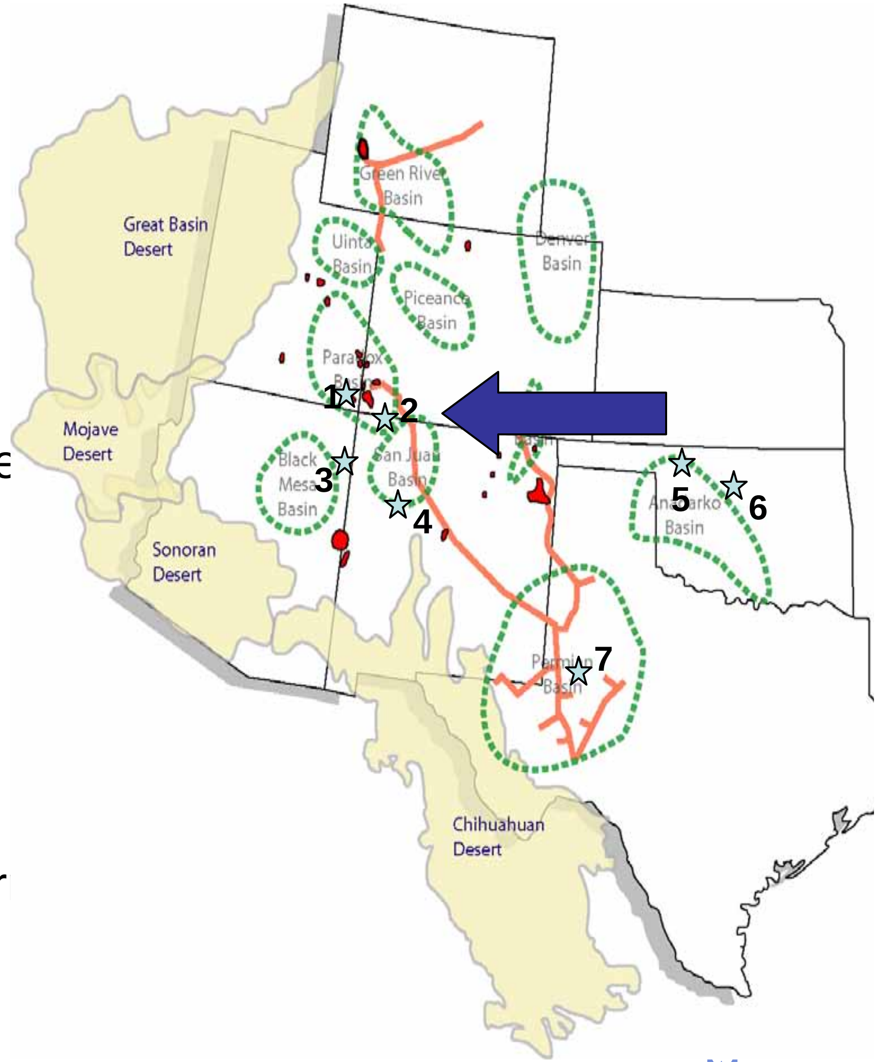


Southwest Regional Partnership on Carbon Sequestration

Four Corners Area

Barker / Ute Domes:

- Folded algal limestone reservoirs – Paradox Formation
- Dakota Formation – second target at 6,000 feet
- > 100 Bcf gas and > 100,000 barrels oil
- Reservoir depth > 8,500 feet
- Within 20 mi of San Juan/Four Corners powe plants



Industry partners <u>in discussions</u> are:

- Public Service Company of New Mexico (PNM)
- Arizona Public Service Company (APS)
- Southern Ute (located in part on Souther Ute Reservation)
- Navajo Nation

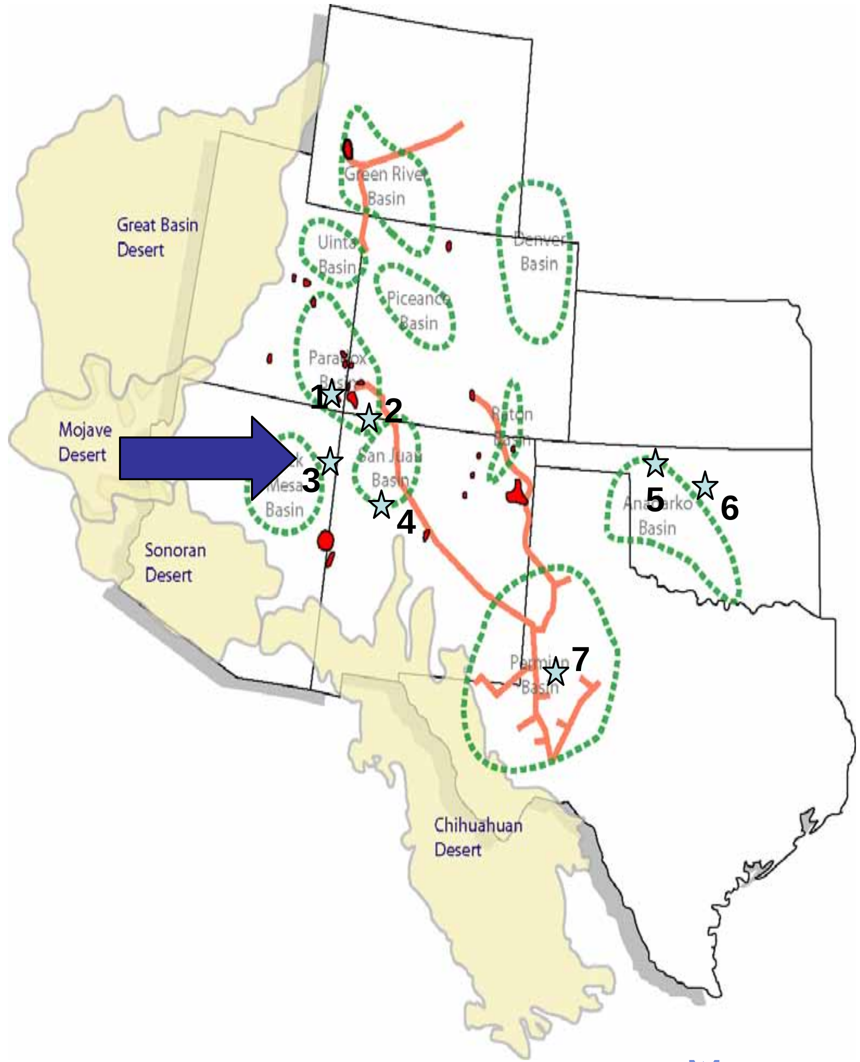
Four Corners Area

Springerville / St. Johns:

- Springerville/St. Johns, Arizona – Site of a natural CO_2 storage reservoir
- Partnership is investigating the potential of subsurface geologic sequestration (recharge the natural reservoir?) associated with CO_2 removed from TEP's power plant near Springerville
- Separation/capture integral

Industry partners <u>in discussions</u> are:

- Tucson Electric Power (TEP)
- Ridgeway Petroleum



Southwest Regional Partnership
on Carbon Sequestration

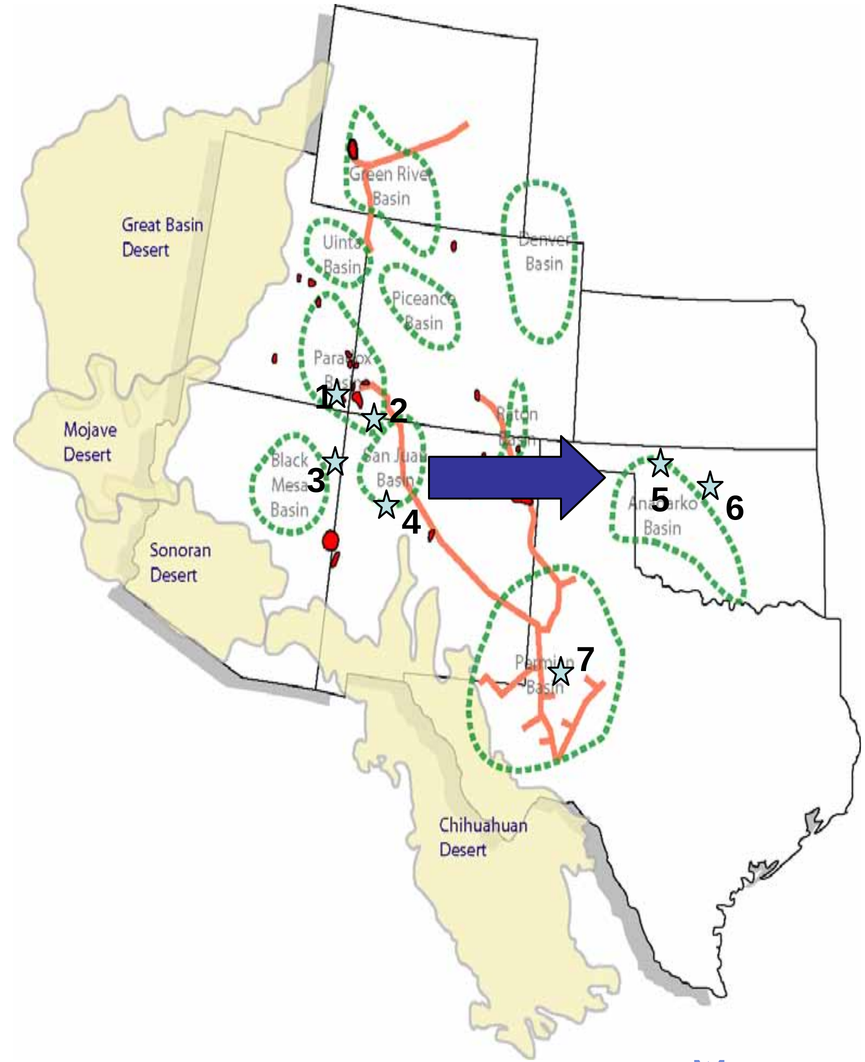
Northern Oklahoma

Deep Saline Opportunity, Woodward:

- Located in Woodward Trench
- Sands and shales of Pennsylvanian age (Morrow)
- Area was a low productivity gas play converted to a few brine producers for iodine extraction
- Individual (low pressure) pipelines from the plant to each well
- Exceptional porosity and permeability
- Suitable for injecting large quantities CO_2
- 4000 BPD → ~ 318 tonnes/day @ 500 kg/m3 CO2 density or 116,000 tonnes/year

Industry partner <u>in discussions</u>:

- The Beard Company



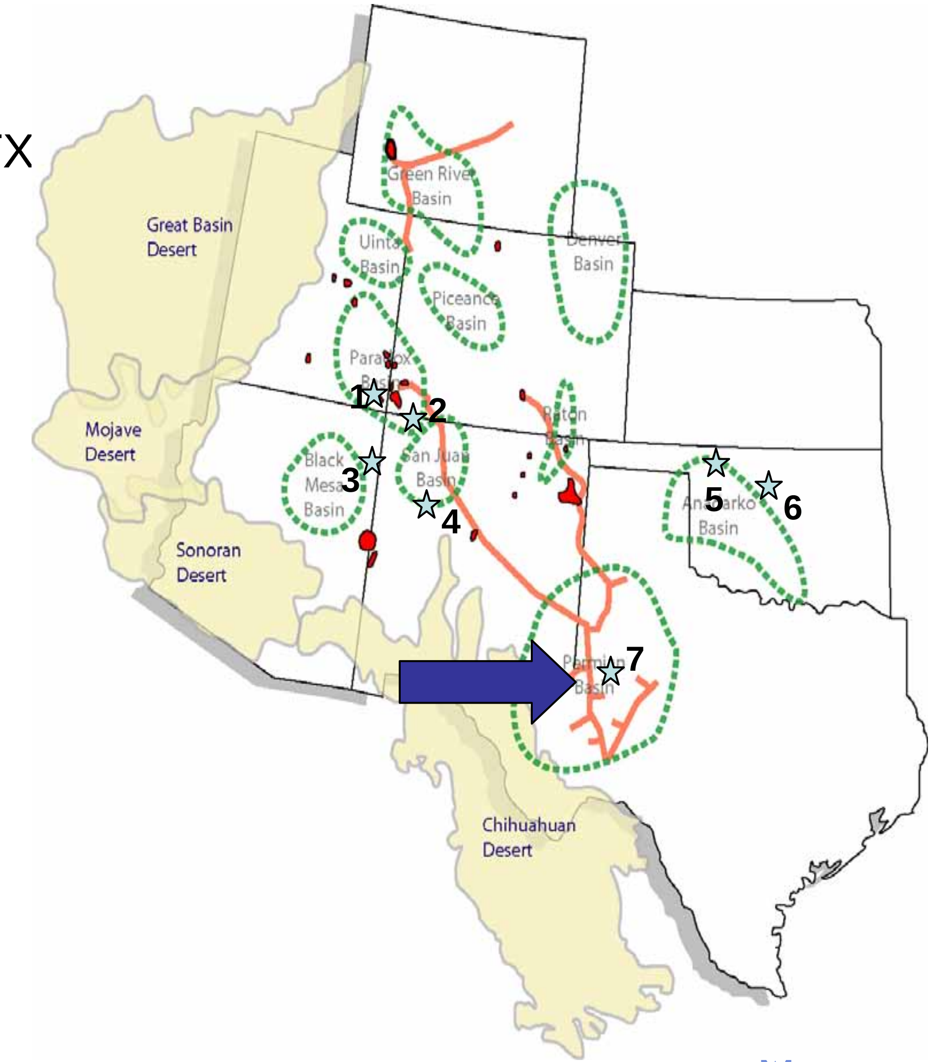
Permian Basin

SACROC and Nearby Fields:

- SACROC Field, Permian basin, west TX (near Snyder, TX)
- Kinder Morgan is almost finished building a new power plant and is planning to attach amine-based CO_2 capture units
- History of decades of CO2 operations
- Extensive CO2 transportation and injection infrastructure
- opportunity for a pilot that includes separation and capture, injection, and extensive MMV.

Potential industry partners <u>in discussions</u> include:

- Kinder Morgan, Statoil, and others.



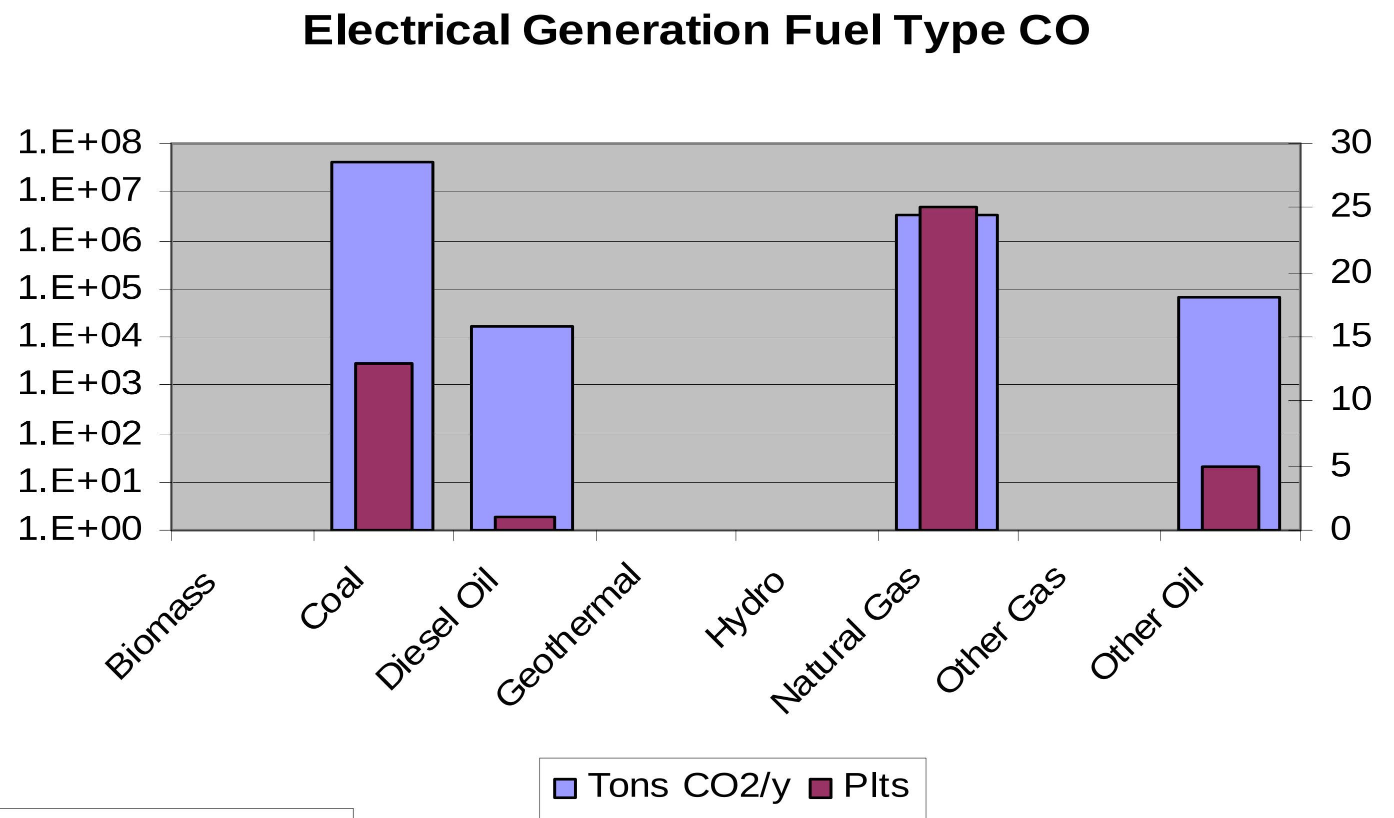
Content in this presentation was developed by the Southwest Regional Partnership, with specific contributions by:

Brian McPherson, New Mexico Tech
Rick Allis, Utah Geological Survey
Joel Brown, USDA
George Guthrie, Los Alamos National Laboratory
Dick Hughes, University of Oklahoma
Dennis Leppin, Gas Technology Institute
Orman Paananen, Sandia National Laboratories
Rajesh Pawar, Los Alamos National Laboratory
Tarla Peterson, University of Utah
Patricia Sullivan, WERC
Genevieve Young, Colorado Geological Survey
and many others in the Southwest Partnership

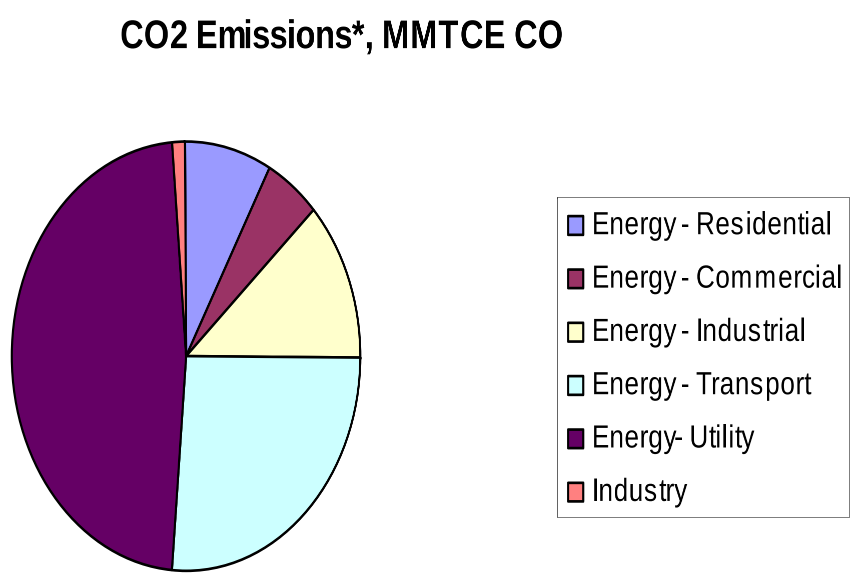
southwestcarbonpartnership.org

[redacted]

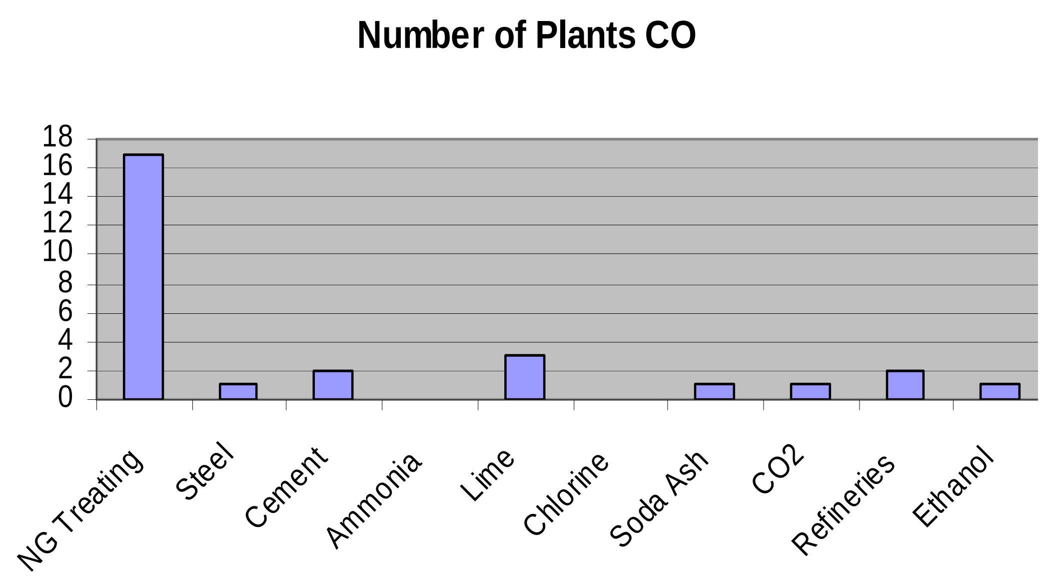
COLORADO



Electrical Generation Fuel Type CO
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
30
25
20
15
10
5
0
Biomass
Coal
Diesel Oil
Geothermal
Hydro
Natural Gas
Other Gas
Other Oil
Tons CO2/y
Plts



CO2 Emissions*, MMTCE CO
Energy - Residential
Energy - Commercial
Energy - Industrial
Energy - Transport
Energy- Utility
Industry



Number of Plants CO
18
16
14
12
10
8
6
4
2
0
NG Treating
Steel
Cement
Ammonia
Lime
Chlorine
Soda Ash
CO2
Refineries
Ethanol

Work Group Coordinators Committee

Public Education & Involvement

CO_2 Sinks & Distributed Sources

Infrastructure, Separation, Capture & Point Sources

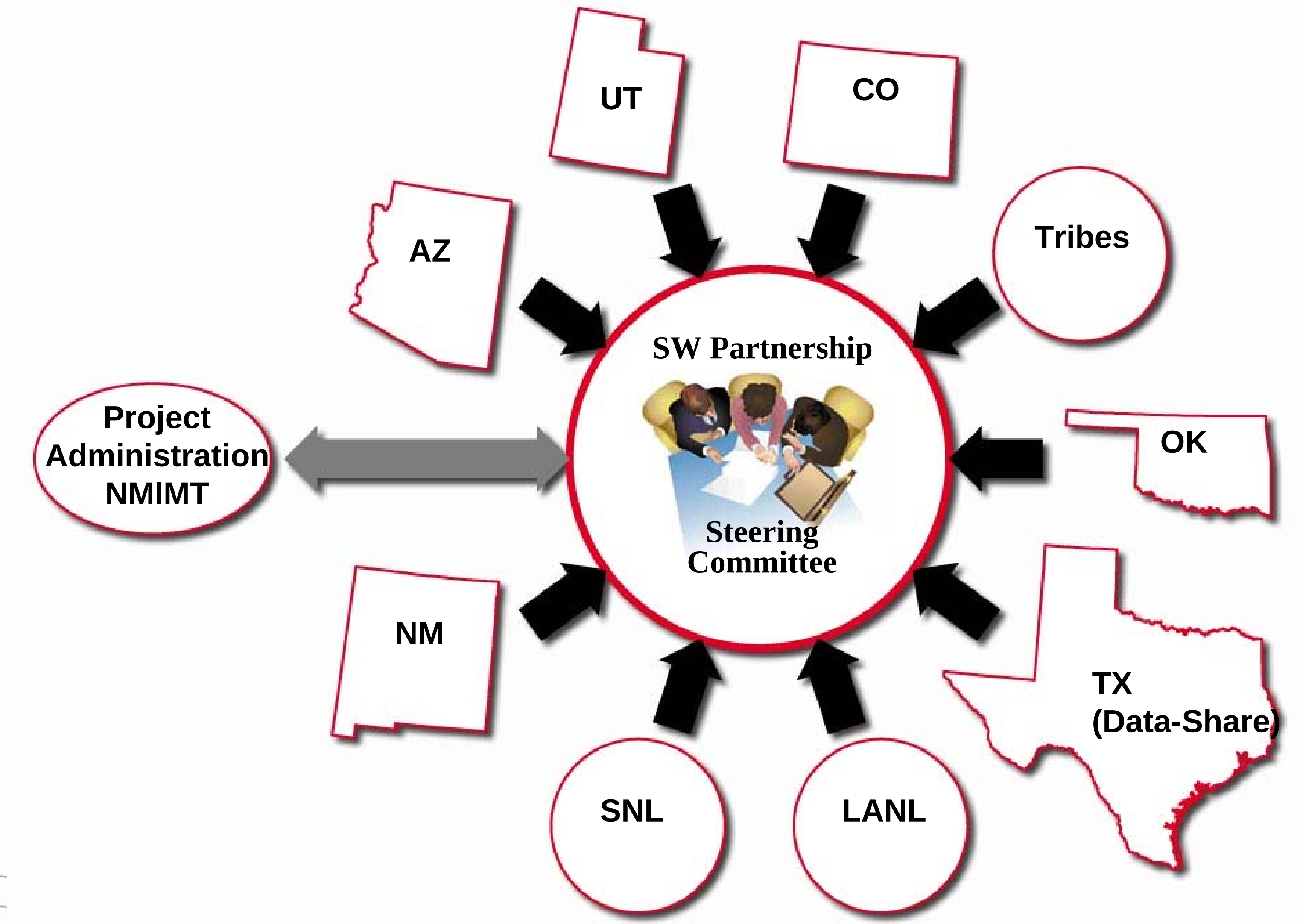
Committee is ensuring appropriate and effective technology transfer and "cross-pollination" of ideas among the working groups

Information, GIS / Database

Regulatory Compliance

Integrated Assessment

Executive Steering Committee



Attribute Table

ArcView GIS 3.2a

File Edit Table Field Window Help Av2Ax

1 of 9 selectec

Attributes of San Juan Basin Pools

Basin	Field_name	Res_name	Temperatur	Pressure	Gas_grav	Latitude	Longitude	Res_type	Disc_year	Usgs_class	Cum_gas	Cum_oil	Cum_water	Max_ann
San Jua	ALBINO	PICTURED CLIFFS (GAS)	128	1435	0.620	36.95170	107.64210	Gas	1974	10	12.3	0.01	0.57	
San Jua	ANGELS PEAK	GALLUP (ASSOCIATED)	70	1650	0.717	36.53100	107.88510	Oil	1958	13	82.1	1.04	0.07	
San Jua	BARKER DOME	PARADOX POOL		2975	0.720	36.97230	108.31740	Gas	1945	14	135.9	0.18	1.29	
San Jua	BISTI	LOWER GALLUP (OIL)	145	1348		36.40040	108.11800	Oil	1955	13	77.3	40.69	46.18	
San Jua	CHA CHA	GALLUP	158	1630		36.66170	108.24340	Oil	1959	11	19.0	10.44	14.63	
San Jua	GALLEGOS	GALLUP (ASSOCIATED)		1540	0.820	36.48750	108.08210	Oil	1954	12	41.9	2.38	0.19	
San Jua	TABLE MESA	PENN C (ABANDONED)	177	3000	0.932	36.60360	108.63750	Oil	1951	9	7.1	0.17		
San Jua	TOCITO DOME	PENNSYLVANIAN D (ASS	130	3217		36.48750	108.78080	Oil	1963	11	28.8	13.26	17.81	
San Jua	UTE DOME	PARADOX (GAS)	174	3628		36.94160	108.28170	Gas	1948	13	111.6	0.09	0.09	

- **Less than 40 reservoir parameters in table**
- **Represents small subset of GASIS database parameters, which exceed 250**
- **Emphasis on minimum data required to calculate CO_2 capacity and injectivity**